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# MD10

## FEATURES

- 3 Video Modes:  
1080p30, 720p60, WVGA 120fps
- 8 Megapixel Still Images, 8fps Burst
- Intelligent Voice Control
- Optional IP-68 Housing,  
Waterproof to 20 Meters

## TECHNICAL SPECIFICATIONS

- Recording Time (Max.)  
Video: About 210 Minutes  
Audio: About 240 Minutes
- Dimensions: 1.34 x 1.10 x 2.05 in.
- Weight: 1.76 oz.

# S60

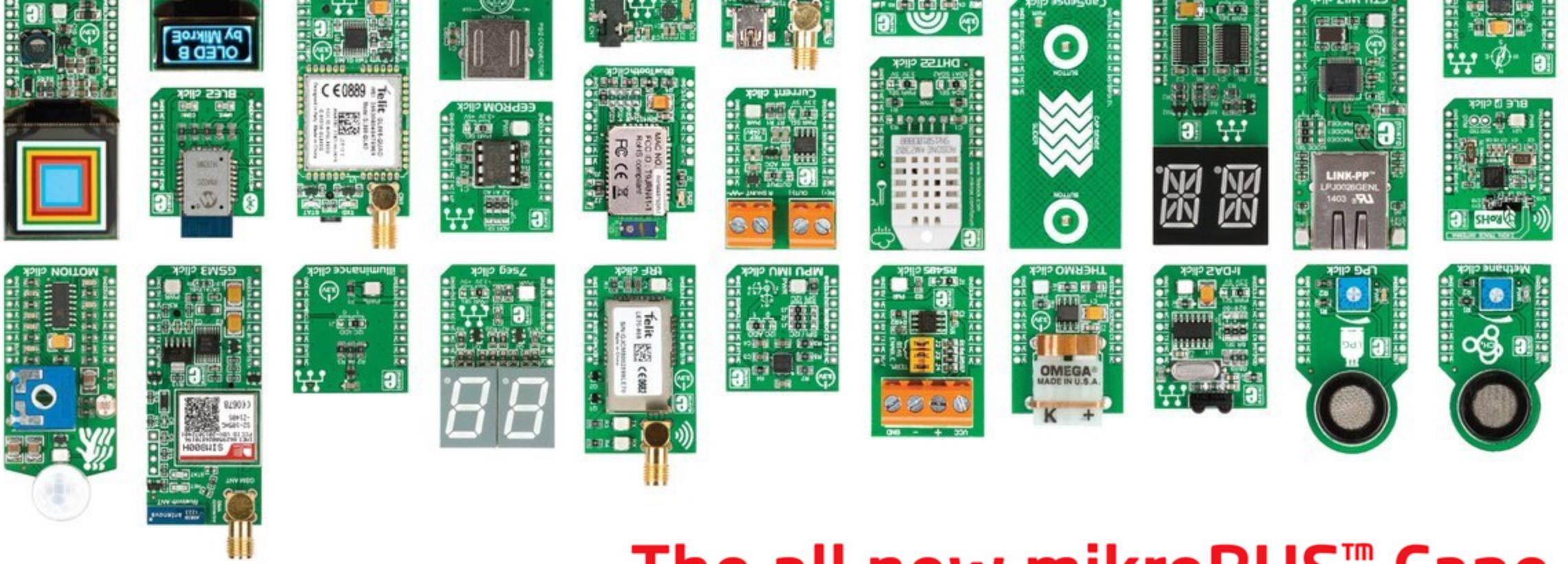
## FEATURES

- 8 Video Modes: 720p120 ~ 1080p60
- 16 Megapixel Still Images, 8fps Burst
- 2-inch LCD Back for Viewing Footage
- IP-68 Housing, Waterproof to 10 Meters

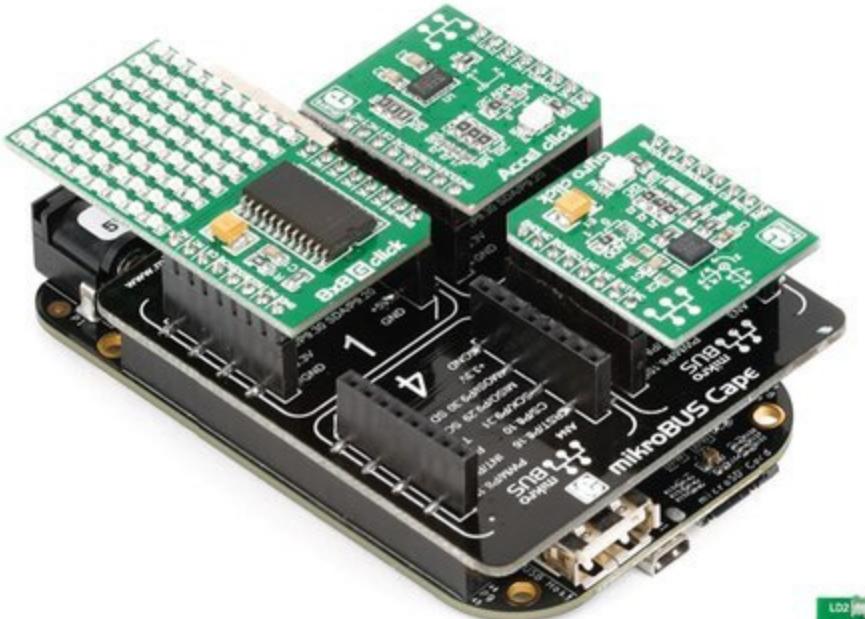
## TECHNICAL SPECIFICATIONS

- Recording Time (Max.)  
Video: About 180 Minutes  
Audio: About 210 Minutes
- Dimensions: 2.32 x 1.69 x 1.38 in.
- Weight: 1.92 oz.

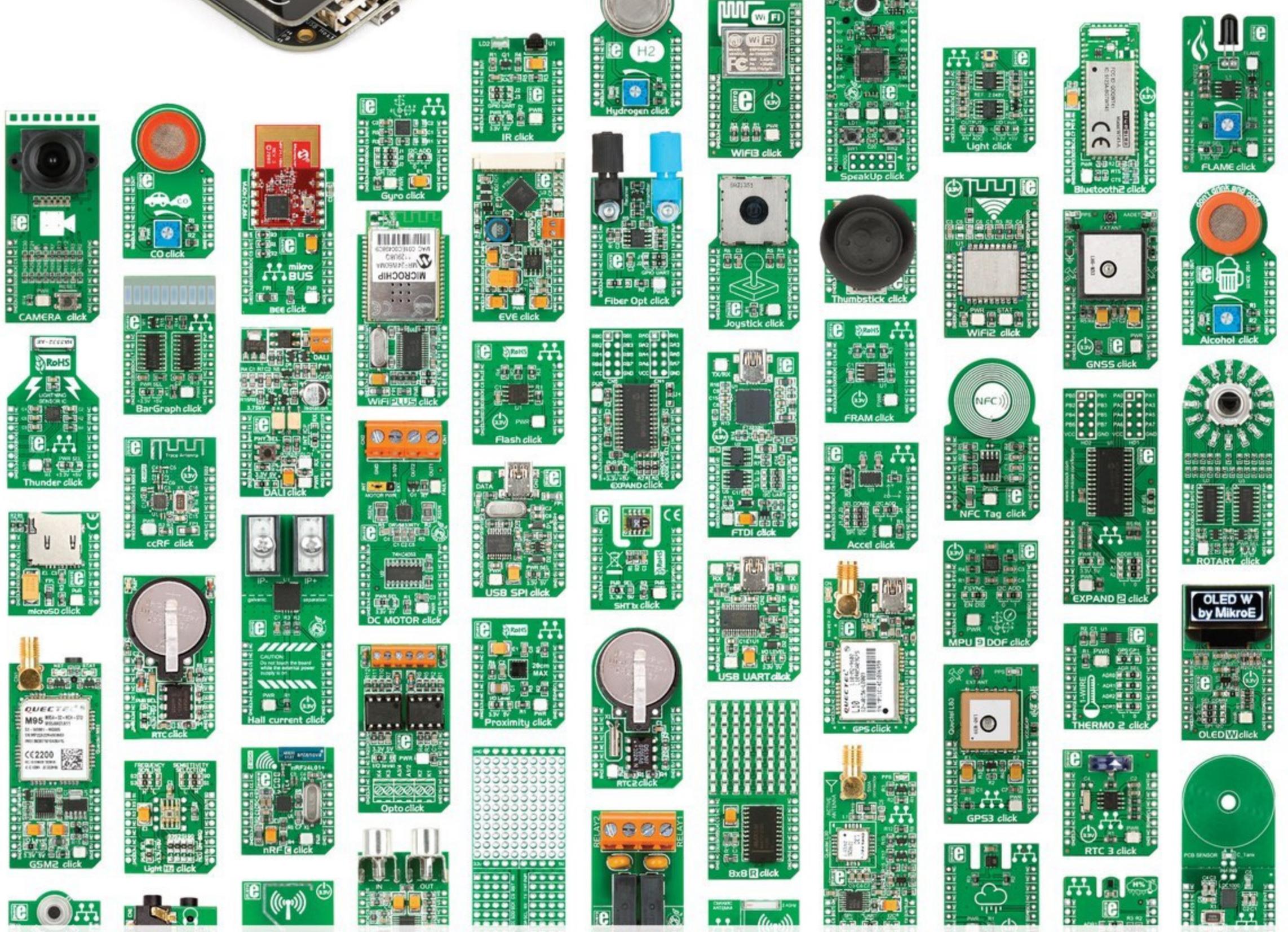
**Hitec****AEE****Action Camera**  
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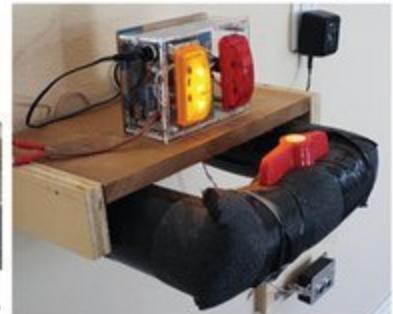
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by Bryan Bergeron, Editor

# DEVELOPING PERSPECTIVES

## Vintage Repair

I'm in the middle of overhauling a vintage Singer 201-2 sewing machine, manufactured in the US in 1940. As I expected, the motor brushes need replacing, the old-fashioned leaf switch controlling the light is — at best — intermittent and needs a good cleaning, and the cotton-insulated wire is begging to be updated to fireproof silicon insulated wire. Old appliances — void of microcontrollers or even simple semiconductors — are a pleasure to tear down and rebuild. They're fun as a solo weekend project, or, if you have someone you want to teach basic mechanics and electricity to, they make a good two or three weekend project. Even bringing an old toaster back to life can provide a sense of satisfaction.

Back to the Singer, there's always more involved in a vintage repair than meets the eye. These old sewing

machines require regular lubricating and cleaning like any other fine metal equipment. I've tried just about every grease on the market, and have come to rely on Tri-Flo clear grease. It's a synthetic grease that's fairly odorless, relatively inexpensive, and easy to come by. Just make certain you remove all of the old organic grease before you apply the Tri-Flo. The combination of old and new grease doesn't perform well.

One of the unfortunate characteristics of lighted appliances from the middle of the last century is that they relied on inefficient 110V incandescent bulbs. The Singer uses a miniature 15W bulb that gets extremely hot — hot enough to blister the paint on the bulb holder. I've solved that problem by replacing the incandescent with a more efficient, much cooler LED version. An unanticipated

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## Subscription Orders

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P.O. Box 15277

North Hollywood, CA 91615

## FOUNDER

Jack Lemieux

## PUBLISHER

Larry Lemieux

[publisher@nutsvolts.com](mailto:publisher@nutsvolts.com)

## ASSOCIATE PUBLISHER/ ADVERTISING SALES

Robin Lemieux

[robin@nutsvolts.com](mailto:robin@nutsvolts.com)

## EDITOR

Bryan Bergeron

[techedit-nutsvolts@yahoo.com](mailto:techedit-nutsvolts@yahoo.com)

## VP OF OPERATIONS

Vern Graner

[vern@nutsvolts.com](mailto:vern@nutsvolts.com)

## CONTRIBUTING EDITORS

Fred Eady

Tim Brown

Jon McPhalen

Jeff Eckert

Paul Verhage

Chuck Hellebuyck

Thomas Henry

Tom Kibalo

Bob Fischer

Bob Fink

Geoff Clark

Larry Coyle

Craig Lindley

## CIRCULATION DEPARTMENT

[subscribe@nutsvolts.com](mailto:subscribe@nutsvolts.com)

## SHOW COORDINATOR

Audrey Lemieux

## WEB CONTENT

Michael Kaudze

[website@nutsvolts.com](mailto:website@nutsvolts.com)

## WEBSTORE MARKETING

Brian Kirkpatrick

[sales@nutsvolts.com](mailto:sales@nutsvolts.com)

## WEBSTORE MANAGER

Sean Lemieux

## ADMINISTRATIVE STAFF

Debbie Stauffacher

Re Gandara

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advantage of moving to LED lighting is that the light is nearly pure white as opposed to yellow. You can find LED bulbs at Amazon, [100bulbs.com](http://100bulbs.com), and, of course, [homedepot.com](http://homedepot.com).

Replacing frayed power cords can be a challenge – especially when the appliance is designed for a non-polarized two-pronged connection to the mains. Arbitrarily connecting a three-pronged plug can be a hazard – especially on an appliance with a metal chassis. Unless you're familiar with electrical code – as well as how your house is wired – I'd stick with the original wiring diagram. Do replace the brittle plastic cord with modern flexible cord. I've had good luck with non-polarized cords from both Amazon and Walmart.

Switches – especially power switches – are the most problematic components in a vintage repair. It's usually easy enough to replace a toggle switch with a garden variety version, but it's at the cost of destroying the "vintage" feel of the appliance. Take the Singer sewing machine switch. The toggle is a distinctive white Bakelite, and the mechanical aspect of the switch is almost two inches long. I was lucky enough to find a new old stock (NOS) replacement on eBay. Otherwise, I would have been forced to substitute a miniature toggle switch for the classic Bakelite toggle. I've found a great source of old fashioned switches is guitar supply houses and local music stores – especially stores that cater to the tube amp crowd.

So, next time you walk past a yard sale, check out the vintage electrical items. There's always something to learn from a teardown, even if you have no need for the actual item. **NV**

## READER FEEDBACK

### Weather Website

In one of Bryan Bergeron's past editorials, he mentioned purchasing a weather station. I've often thought of building or buying my own weather station, but I never seem to find the time to do it.

Living in southern CA, I wanted to add seismic sensors, in addition to the standard array of sensors (wind speed, direction, temp, humidity, barometric pressure, rainfall, etc.). It'd be cool to be able to set up a weather website, so my neighbors could see the conditions. I wonder what make/model system Bergeron finally settled on.

I emailed both Davis and AcuRite, and they have told me – in no uncertain terms – that neither of their systems can be made to work with "homebrew" sensors. So, maybe the easiest way to go would be to start with a standard model weather station – from either Davis or AcuRite – and have it upload the weather data to a website.

Then, I could design my seismic sensors and upload the data to that

website as a separate process, using a microcontroller (sort of in parallel to the weather station).

Any thoughts on this would certainly be appreciated. It might be doable, but I'm no expert on this.

**Jeff Kerner**

*I ended up modifying an ancient but workable Heathkit weather station that a friend was about to toss out. It was a fun project, going from analog to digital. You have an ambitious project; really data fusion.*

*I like the idea of parallel treatment of data. You get more than the simple sum of the parts.*

*You could write a simple data feed from an Arduino to process on your Mac/PC and do some nifty graphics/analysis in real time.*

*Bryan Bergeron*

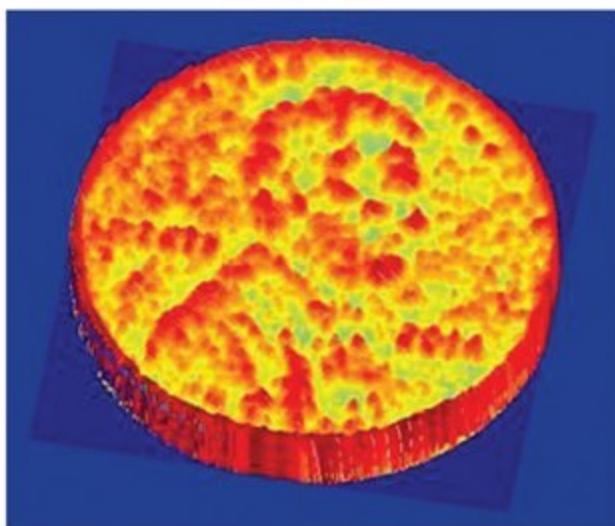
### School of Hard Shocks

When I received my May 2015 *Nuts & Volts*, I read it cover to cover.

*Continued on page 33*

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## ADVANCED TECHNOLOGY



■ Micrometer resolution of a penny taken from 1.5 ft away.

### From Smartphone to 3D Printer

**A**t present, if you want to create something using a 3D printer, you first generate a digital model using a software package like Blender, OpenSCAD, or even AutoCAD. However, the process eventually may be as simple as taking a photo of something using your smartphone and sending the data to the printer, thanks to a camera chip developed at the California Institute of Technology ([www.caltech.edu](http://www.caltech.edu)).

Your existing camera basically just catches pixels of incoming light without reference to how far away an object is. The CalTech chip — called a nanophotonic coherent imager (NCI) — uses LIDAR, which illuminates the target with a laser and analyzes the reflected light to provide both distance and intensity data.

"By having an array of tiny LIDARs on our coherent imager, we can simultaneously image different parts of an object or a scene without the need for any mechanical movements within the imager," noted developer Prof. Ali Hajimiri.

Using coherent light, it is possible to detect the phase, frequency, and intensity of the reflected light from different points on the object, which is sufficient information to create a highly accurate 3D image. In the illustration, micrometer-scale resolution was obtained on a penny from a distance of about 1.5 ft (0.5 m).

The prototype NCI consists of an array of only 16 coherent pixels, which isn't all that useful. In fact, the image of the penny was created from a series of 4 x 4 pixel sections. Hajimiri says the current array of 16 pixels could be easily scaled up to hundreds of thousands.

With these larger arrays, the imager "could be applied to a broad range of applications from very precise 3D scanning and printing, to helping driverless cars avoid collisions, to improving motion sensitivity in superfine human machine interfaces." ▲

### Method for Cancelling Shockwaves

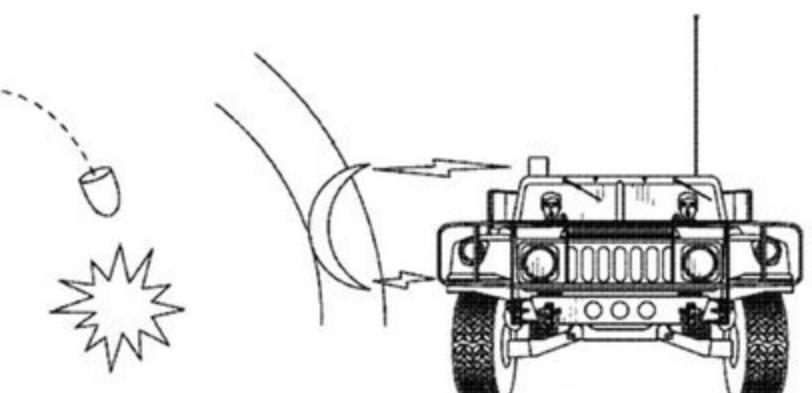
In today's conditions of asymmetric warfare, explosive devices pose a major hazard to soldiers and equipment. Most of the damage is created by two threats: flying shrapnel and shockwaves. Shrapnel often can be handled using armor and other physical barriers, but shockwaves are more difficult to deal with. By definition, shockwaves are "traveling discontinuities in pressure, temperature, density, and other physical qualities through a medium," and they can pass through intermediate media.

However, it was recently reported that Boeing Co. ([www.boeing.com](http://www.boeing.com)) has been working on a method of creating a shock-attenuating force field and, in fact, recently was issued a patent on its "Method and system for shockwave attenuation via electromagnetic arc."

One is tempted to think in terms of a force field such as popularized in science fiction, but in reality it is more analogous to the operating principles of a noise-cancelling microphone. In the Boeing concept, the system — perhaps mounted on a Humvee — visually detects and analyzes an explosion, then before the resulting shockwave can reach the vehicle, creates an opposing protective shockwave.

It does so by sending out laser pulses that ionize the intervening air and forms a plasma channel. The channel — via deflection, absorption, reflection, and refraction — minimizes damage to the vehicle.

There is no indication of when or if such a system will be ready for deployment, but there is no reason why it can't also be applied to aircraft, naval ships, and even buildings. ▲



■ Illustration of shockwave attenuation system from patent application.

# COMPUTERS and NETWORKING

## Chromebooks Down to \$149

**A**lthough initially scoffed at by market analysts, Chromebook sales were up by 85 percent in 2014 and, in fact, accounted for 14 percent of the laptop market. Contributing factors include widespread adoption in K-12 schools and continuously plunging prices. The expanding market is attracting new players, one of which is Hisense USA ([www.hisense-usa.com](http://www.hisense-usa.com)) — a more traditional vendor of televisions, refrigerators, air conditioners, dehumidifiers, etc.

Hisense recently introduced a \$149 unit that, according to one prominent reviewer, "actually isn't awful." Low-end machines don't have many features to dwell on, but it's worth mentioning that it runs on a 1.8 GHz quad-core Rockchip processor (Cortex A17), incorporates a 16 GB SSD, and features dual-band 802.11ac and Bluetooth networking. As with most el-cheapo devices, the display is nothing to write home



The first venture into the Chromebook market by Hisense USA.

about, but it does boot up in less than 10 seconds, and it offers two USB 2.0 ports, HDMI, and a headphone jack. Battery life is said to be "up to 8.5 h." It's available at a Walmart near you. ▲

## Give Your Device the Finger

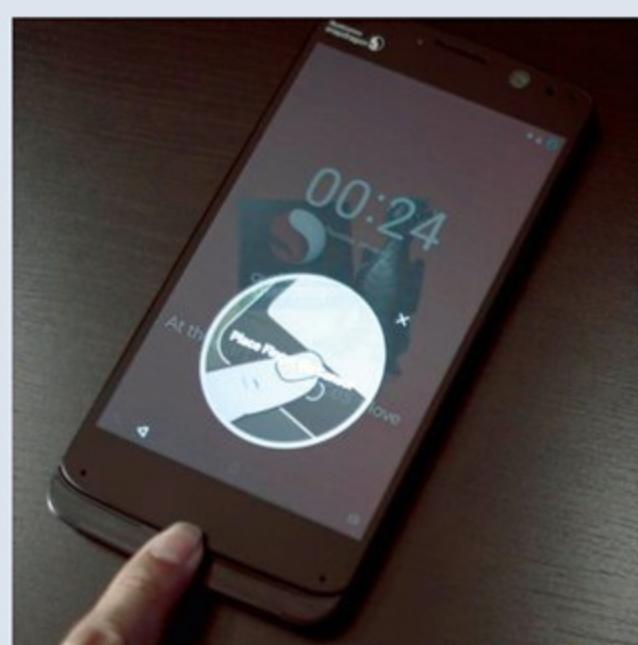
**W**e're all more or less accustomed (or at least resigned) to the standard userid/password security procedure. It's a very bad idea to use the same login for all of your devices and websites that need to be secure, so you now have dozens of IDs and passwords — all scrawled in a notebook or on the back of an envelope somewhere because there's no way you can remember them all. An obvious solution is biometric authentication, which can be based on recognition of things like irises, ear shapes, olfactory sensing, and (most popularly) fingerprint recognition.

Fingerprint scanning can be done using several technologies, with the most common being optical and capacitive (e.g., Apple's Touch ID). Unfortunately, both

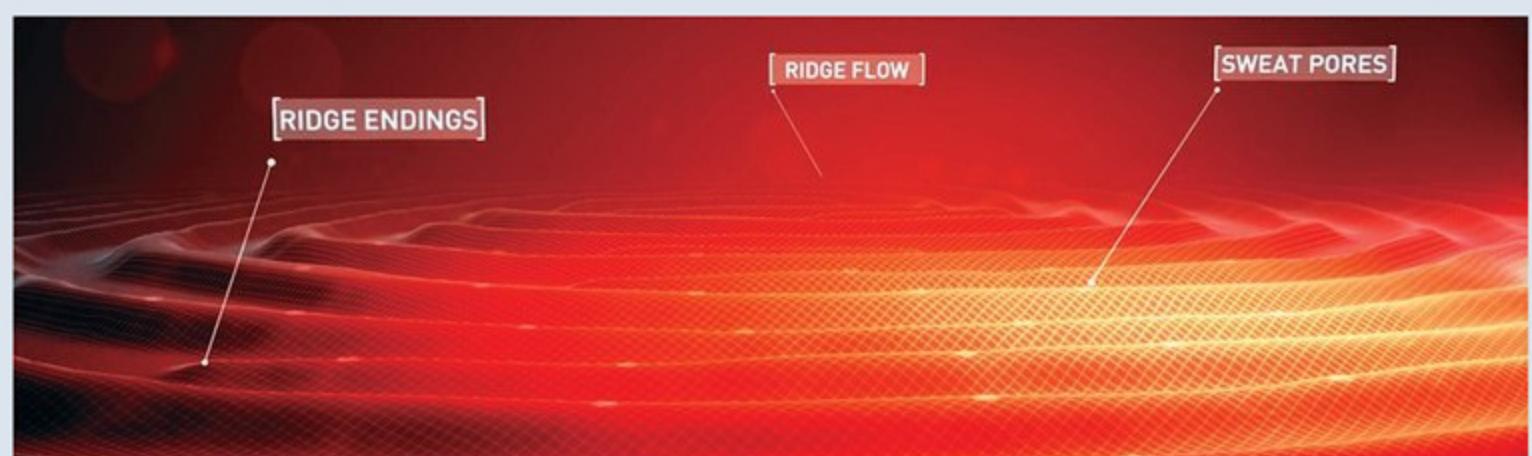
are subject to glitches. Issues such as temperature and humidity (which both affect the capacitance of your skin), dirt, scan

angle, cuts and scrapes, and other factors can negatively affect recognition accuracy, and if your fingers get shriveled up in the shower or ocean, they may be temporarily unrecognizable. However, Qualcomm Technologies ([www.qualcomm.com](http://www.qualcomm.com)) is now offering manufacturers the "mobile industry's first comprehensive 3D fingerprint authentication solution based on ultrasonic technology."

The Snapdragon Sense™ID 3D Fingerprint Technology is said to have some advantages over other approaches, including the ability to scan through a smartphone cover made of glass, aluminum, stainless steel, sapphire, or plastics, and it can scan through such contaminants as sweat and hand lotion to provide more accurate identification. Additionally, the sound waves directly penetrate the outer layers of skin to detect 3D details and unique fingerprint characteristics, including ridges and sweat pores that capacitive sensors can't pick up. The result is "a highly detailed surface map of the fingerprint which is difficult to imitate or spoof." The Qualcomm system should be appearing in commercial devices later this year. ▲



Qualcomm's new Snapdragon Sense technology picks up 3D details using ultrasonics.



# CIRCUITS and DEVICES

## Low(er) Priced Network Audio Player

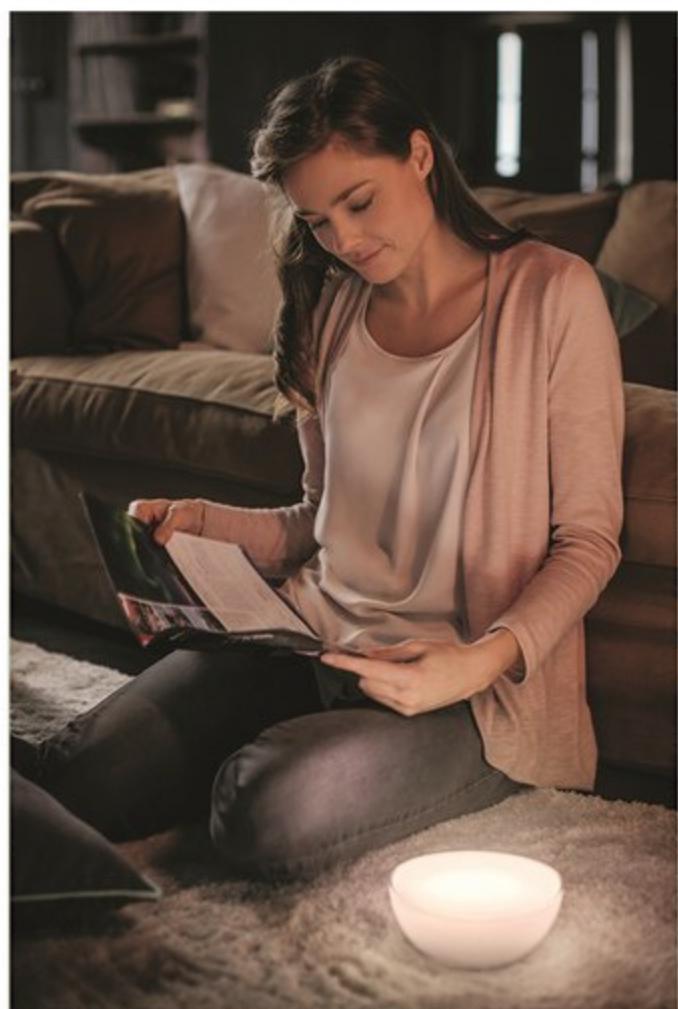
Since the 1970s, the Marantz name has been attached to high quality equipment prized by audiophiles, and although Saul Marantz shut down the Kew Gardens, NY production facility long ago, the brand still produces some top-shelf receivers, Blu-ray players, and other Hi-Fi components in Japan. As physical media are being replaced by networked audio files, one would correctly expect the company to offer some high-end network players such as the NA-11S1, which is priced at a hefty \$3,499 and is beyond most budgets. However, the good news is the new NA6005, will run you "only" \$649. It features both Wi-Fi and Bluetooth technology, as well as proprietary Marantz audio technologies to offer advanced connectivity and sound performance.

Through built-in Wi-Fi or an Ethernet port, the NA6005 connects to a home network to access Internet radio stations and streaming services like Spotify Connect®. It's also equipped with Apple's Airplay® so users can stream their iTunes® music (from a Mac or PC), as well as directly from an iPhone®, iPad®, or iPod Touch®.

Users can also access local file libraries on a network attached storage (NAS) device or a computer media server, and play audio file types including WAV, WMA, MP3, and AAC. Moreover, the NA6005 can play back high resolution audio files including DSD 2.8 MHz/5.6 MHz, FLAC 192/24, WAV 192/24, AIFF, and ALAC. Of course, you'll also need to pick up a PM6005 integrated amplifier (\$699) and a CD6005 CD player (\$499) to complete the system. ▲



■The Marantz NA6005 network audio player.



■ Hue Go: Lifestyle enhancement or just a glowing bowl?

## Let There Be Light

The lighting industry has brought forth many changes in recent years, including the widely despised CFLs, various arrangements of LEDs, and (perhaps soon) graphene bulbs. One of the latest introductions is the Hue Go lamp from Royal Philips ([www.usa.philips.com](http://www.usa.philips.com)). At first glance, a portable lamp seems pretty mundane, but it won an iF International Forum Design award and features five new patented light effects that "enrich special moments." It also offers interaction with more than 200 third-party apps. According to Philips' Sridhar Kumaraswamy, "We envisage all lights to be connected. Put simply, lighting is now central to the Internet of Things, and we see Philips Hue as the go-to lighting brand for the home."

Among its attributes is portability, and the Hue Go can be used throughout the home; when unplugged from the power supply, it becomes a portable centerpiece that operates for up to three hours in battery mode. The bowl-shaped device can be positioned in different ways, so you can use it for an intimate dinner, to light up a wall, or whatever.

More interesting is that you can choose from seven different lighting effects ranging from warm white to bright daylight, or one of the five effects called cozy candle, Sunday coffee, meditation, enchanted forest, and night adventure. With the Hue app, you can choose from more than 16 million colors. Finally, the Hue Go can provide "light notifications" if you receive a

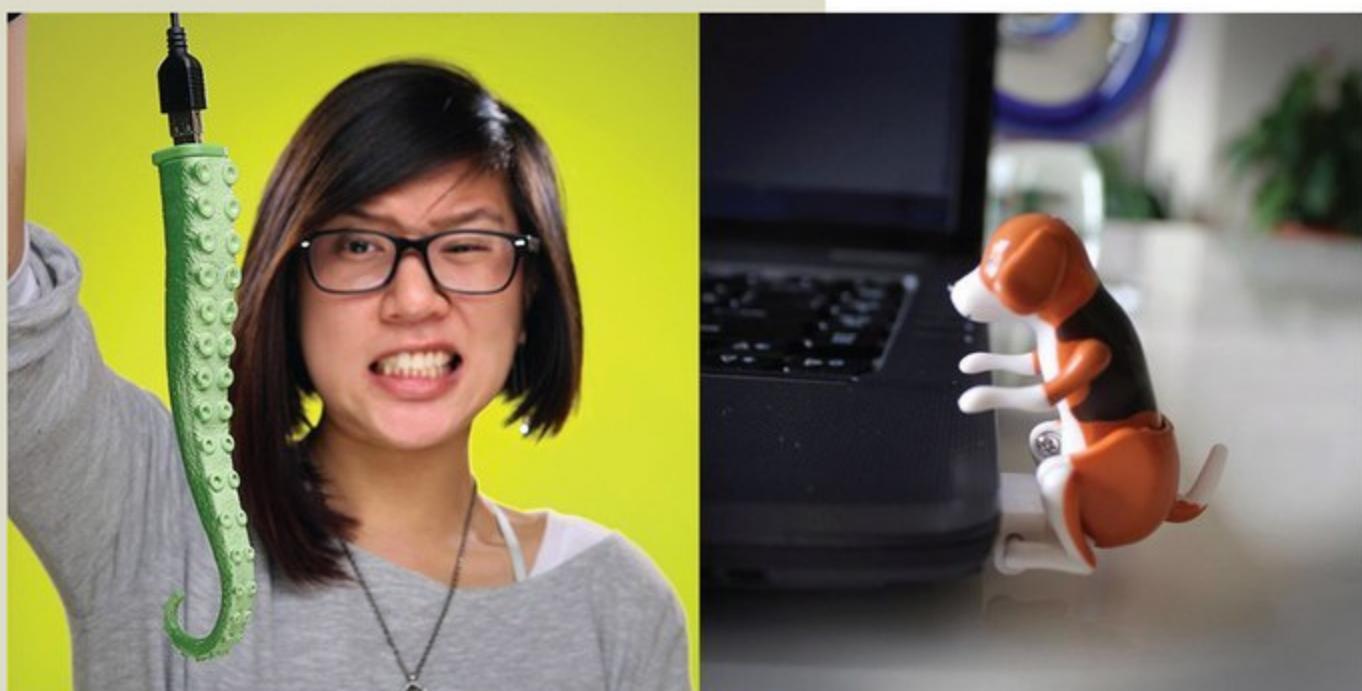
new email or a weather alert, or something else of interest occurs.

One might wonder: Is this glowing bowl a bona fide contribution to the modern lifestyle or just an overhyped reincarnation of the lava lamp? For \$99.95 (US pricing yet to be announced), you can judge for yourself. ▲

# CIRCUITS and DEVICES Continued

## Useless Serial Bus

Computer peripheral designers have created dozens of (arguably) clever Flash drives that look like something else, including sushi, guitars, cheeseburgers, and human thumbs. Most of the gadgets run the gamut from 256 MB to 16 GB, so they are functional as well as weird. Now, you can plug up an unused USB port with the USB Squirming Tentacle, which has the distinction of offering no storage at all. It basically just sucks power from the port and wiggles, although the folks at Think Geek ([www.thinkgeek.com](http://www.thinkgeek.com)) caution that — having been inspired by H. P. Lovecraft's Cthulhu deity — it "may summon the Elder Gods from the depths." Maybe it offers \$14.99 worth of amusement — especially at work, in airports, or in other public places. On the other hand, you may get more laughs from the USB humping dog, available from Oddity Mall ([odditymall.com](http://odditymall.com)) for only \$10.50. ▲



■ Your choice: Wiggly or humpy?

# INDUSTRY and the PROFESSION

## 3D Printed Cars? For Real?

The advent of 3D printing has ushered in some intriguing concepts, but probably none so much as the one envisioned by the folks at Local Motors ([localmotors.com](http://localmotors.com)). According to the company, "Gone are the days of mega- or even giga-factories that consume tremendous amounts of time and energy to fabricate products. A more sustainable, nimble, and flexible factory is on the horizon. Called microfactories, these diminutive factories drastically change how we produce large consumer goods for unique local needs." The most interesting part of it is that these microfactories are intended to produce cars. Yes, human-size cars (and motorcycles, tricycles, and other vehicles) that actually can be driven, and are predominantly manufactured using 3D printers.

Impossible? Apparently not. They have already built one called the Strati, and every part that can be integrated into a single-material piece has been printed including the chassis/frame, exterior body, and many interior features. Everything else (battery, motors, wiring, etc.) has been lifted from Renault's electric city car, the Twizy.

The Strati takes 44 hours to print, but Local Motors intends to reduce that to 24 hours eventually. The process is

referred to as big area additive manufacturing (BAAM), which is really just 3D printing on a larger scale. The Strati is pretty simple, sporting your choice of a 5 or 17 HP motor and an automatic single-speed transmission. Top speed is about 50 mph (80 kph), with a 62 mile (100 km) range from a 3.5 hour charge.

Key to the microfactory concept is that Local Motors' cars will not be produced in a large factory in Detroit or Tennessee, but in many small factories scattered across the world (hence, the "local" part). The company intends to open 100 such facilities over the next 10 years.

If you have a desire to become an automotive tycoon in your own area, give them a call. In the meantime, feel free to interact with the website which is designed to be a "free online and physical workspace where creativity, collaboration, and design drive vehicle innovations." Local Motors has a simple request: "Help us bring badass vehicles to life." NV



■ Local Motors' Strati, a drivable 3D printed car.

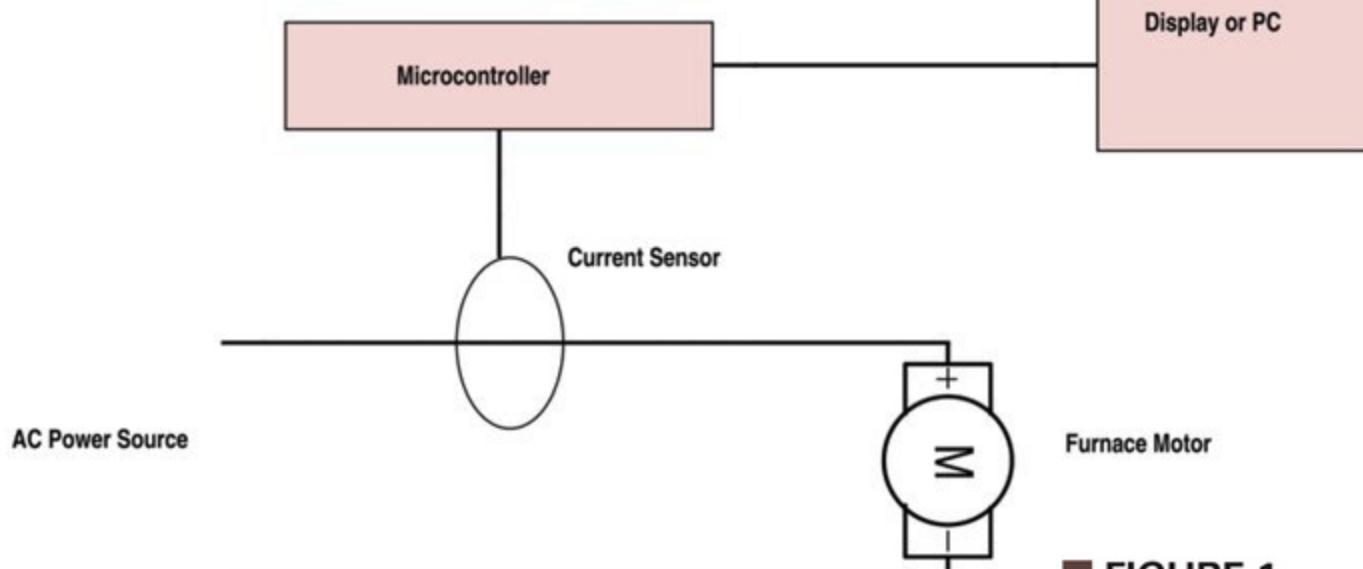
In this column, Tim answers questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions. **Send all questions and comments to: Q&A@nutsvolts.com.**

## Furnace Data Acquisition

**Q**I am looking for a “dongle” that I can hook up to my furnace to collect data about running time. I have a simple running time meter across the burner motor. This tells me the total time but not how long it is running or what time of day it ran. Is there a simple low cost data-acq device with a built-in internal clock and battery? I can put a relay with contacts or a TTL level on the furnace, no problem. What I am thinking of is something that can be installed on the furnace for a month to collect data, then unplug it and insert it in a USB port, download my data from it, then use a spreadsheet to analyze any ideas.

— Edward Ganshirt  
via email

**A**You have a great idea. Monitoring gas and oil fired furnaces is a good way to check the health of our vital heating systems and a good way to save money while helping to cut pollution and energy usage. I was able to find a couple of websites that may provide the furnace runtime data logger you are looking for, and I am sure there are many more systems. See [www.energytools.com/DataWatcher.htm](http://www.energytools.com/DataWatcher.htm) (Energy Tools runtime data watcher) or [www.onsetcomp.com/products/data-loggers/ux90-004](http://www.onsetcomp.com/products/data-loggers/ux90-004) (HOBO on/off motor logger) for more information.



Microcontroller Furnace On Time Monitor Black Diagram

- **Furnace Data Acquisition**
- **Electronics Around Vehicle Fuel Tanks**
- **Mailbag**

Both devices have external current sensors, so you do not have to break a motor wire which could cause problems when you remove the data logger. Both units are battery powered and should be able to track your furnace's operation for a heating season, and have software which can display the data graphically to make interpretation easier. The down side is the unit with software will cost a couple of hundred dollars.

If you are into programming, you could rig up a microcontroller (e.g., Arduino, BASIC Stamp, Microchip PIC) and program it to log the on/off times, time of day, etc., but this would involve program development — especially if you wanted graphics capability.

**Figure 1** is a block diagram of a microcontroller-based furnace monitor. Being able to monitor furnace runtimes could help determine the effectiveness of energy improvement projects and detect furnace problems before you are left without any heat. There are other systems which monitor temperatures, fuel flow rates, etc., but they are more expensive and require sensors to be inserted into the furnace.

Hopefully, some of our readers have experiences they can share with us on their successes and failures with furnace monitoring.

## Electronics Around Vehicle Fuel Tanks

**Q**Please explain the safety concept applied to the electrical circuits in vehicle fuel tanks. Normally, when designing electrical circuits for application in potentially explosive environments, one of the following two approaches are employed: 1. The circuit is designed to be intrinsically safe, i.e., under a worst case fault condition, there can never be enough joules available to cause an explosion; or 2. The potentially hazardous electrical circuit is contained in a UL listed explosion proof box located within the potentially explosive environment.

The box is designed in a manner that if potentially explosive material leaked into the box and there was an explosion, it would be

## QUESTIONS and ANSWERS

Post comments on this article at  
[www.nutsvolts.com/index.php?/magazine/article/august2015\\_QA](http://www.nutsvolts.com/index.php?/magazine/article/august2015_QA).

## MAILBAG

### Re: Burn Marks on LCD TV Screen

Thanks for answering my question in the March issue of Nuts & Volts. I turned down the backlight and the brightness, and that resolved most of the problem. I used a snow pattern and a pixel protector, but neither worked. Probably because the image is too persistent. Thanks again.

Mark Erickson, El Paso, TX

*Mark, I am glad I could help you. Technology today is moving so rapidly it is sometimes hard to keep up with. So, the questions of our readers are helping me to stay on top of the rapidly changing field of electronics.*

### Re: Op-Amp Accuracy Question

Thank you for the answer to my question on op-

amp accuracy in the May 2015 issue. It was exactly the answer I was looking for. I will order the Analog Devices part and test it for future use. In the past, I have found that any trim pots in the circuit are subject to temperature variations that add to the inaccuracy.

Also, I need to look for an app that gives me lunar-planetary alignment. Thanks.

Milton

*Milton, that is what I love about doing the Q&A – helping readers solve their electronic problems. A couple of websites for astronomy apps for the iPhone are: [www.businessinsider.com/11-best-astronomy-apps-for-amateurs-2013-10](http://www.businessinsider.com/11-best-astronomy-apps-for-amateurs-2013-10) and [www.iphoneness.com/iphone-apps/top-astronomy-applications-for-iphone/](http://www.iphoneness.com/iphone-apps/top-astronomy-applications-for-iphone/).*

contained and not propagate beyond the box. Obviously, with the joules potentially available in a vehicle fuel tank, the design is not intrinsically safe; nor are the electrical circuits in the fuel tank housed in an explosion proof box.

Please explain the concept employed to prevent explosions in vehicle fuel tanks.

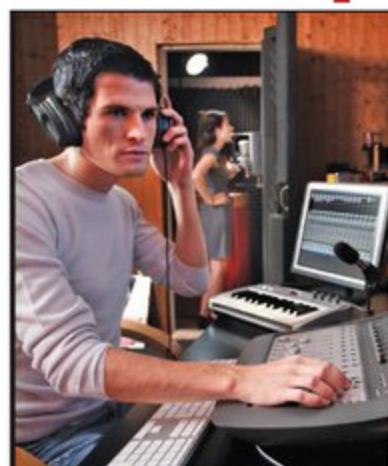
— Dennis Quinn  
via email

**A**If you are not a licensed electrician, you are mighty insightful into a deep, dark secret of the electrical trade. The National Fire Protection Association's National Electric Code (NEC) Article 500 classifies areas where gasoline vapors are (Division 1) or may be present (Division 2) as a Class I/Group D hazard location (there are also temperature and zone classifications, but I am trying to keep it simple). So, fuel tanks would be classified as Class I/Group D/ Division 1 locations when specifying the necessary safety precautions for electrical/electronic equipment. [The NEC is written to cover every conceivable situation, and is thus a very complicated volume which is for those who really like to read and follow various circuitous paths to find a simple answer.]

I worked in a Class I/Group D/ Division 1 chemical plant and our electrical installations were both

expensive and exacting: A general-purpose enclosure was made of stamped sheet metal with a simple latch, whereas an "explosion proof" enclosure was cast aluminum with 20 or 30 bolts to close the gasketed cover, and the threaded hubs were designed for a tight seal to prevent infiltration

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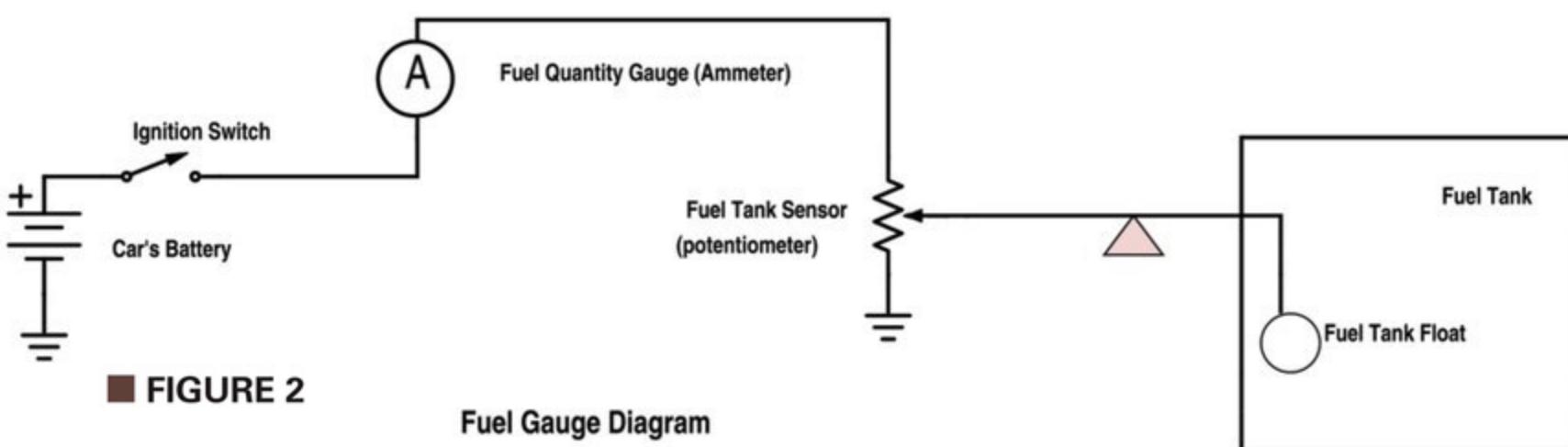
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■ FIGURE 2

Fuel Gauge Diagram

of flammable vapors which would make the panel a tiny bomb.

The conduit had to be the rigid type (not EMT) and had a large number of threads to be engaged. Plus, conduit from boxes and going between walled areas had to be sealed with a material which is like a cross between concrete and grout (pity the electrician that had to pull out the wiring once the sealing compound had set). You are right on target with the methods approved for ensuring the electrical installation is explosion proof: enclosing the electrical circuits (the enclosure I just described); or be intrinsically safe, meaning the circuit does not produce enough energy during normal operation to ignite a flammable vapor-air mixture.

NEC Article 504.2 defines intrinsically safe devices as "Simple Apparatus: An electrical component or combination of components of simple construction with well-defined electrical parameters that does not generate more than 1.5 volts, 100 millamps, and 25 milliwatts, or a passive component that does not dissipate more than 1.3

watts and is compatible with the intrinsic safety of the circuit in which it is used."

For example, our plant used thermocouples to measure temperature which produced only up to 100 millivolts. So, these circuits were "intrinsically safe" (we still enclosed

the wiring in rigid conduit for protection). We also used bubble level meters that bubbled nitrogen into storage tanks, but later switched to explosion proof capacitive meters (airliners use them) which were compatible with our computer control system.

With me (and OSHA et al.), human safety is paramount so I don't cut corners where life and limb is concerned. I purchase commercial devices that have been repeatedly tested and approved. I know that is not what our DIY readers want to hear, but I stand firm on this issue. You have only one life, so take as many precautions as you can.

A good example of electronic devices in fuel systems are those in modern automobiles: the fuel pump and level sender. The pump is mounted in the tank with an external explosion proof motor and an impeller made of spark proof material (in case you run out of gas and air is present with the impeller accidentally contacting the metal in the fuel tank). The sender is mounted inside the fuel neck and uses a float activated potentiometer (variable resistor) which is sealed from the fuel vapors since it operates at 12 volts (i.e., not intrinsically safe). Refer to Figure 2 for a diagram of the automotive fuel gauge system.

**WARNING:** Our readers should NEVER develop a circuit or device for use in fuel tanks because of the inherent dangers to yourself and others (seeing the results of fuel tank fires on TV and the Internet I think of the gasoline tank as a small nuclear weapon). I am a licensed engineer (Chemical, Mechanical, and Electrical) with over 40 years of experience and I would not attempt to construct such a device. So, don't any of you either. I don't want to see you on the evening news as the latest catastrophe.

I hope this answers your question and gives you a humongous fear of fuel system explosions. **NV**

## Feedback Motion Control

### The Old Way

- 1) Build robot
- 2) Guess PID coefficients
- 3) Test
- 3a) Express disappointment
- 3b) Search Internet, modify PID values
- 3c) Read book, modify PID coefficients again
- 3d) Decide performance is good enough
- 3e) Realize it isn't
- 3f) See if anyone just sells a giant servo
- 3g) Express disappointment
- 3h) Re-guess PID coefficients
- 3i) Switch processor
- 3j) Dust off old Differential Equations book
- 3k) Remember why the book was so dusty
- 3l) Calculate new, wildly different PID coefficients
- 3m) Invent new, wildly different swear words
- 3n) Research fuzzy logic
- 3o) Now it is certainly not working in uncertain ways
- 3p) Pull hair
- 3q) Switch controller
- 3r) Re-guess PID coefficients
- 3s) Switch programming language
- 3t) Start a new project that doesn't need feedback control
- 3u) See parts in box. Feel guilty. Go back to old project
- 3v) Start testing every possible combination of PID coefficients
- 3w) Apply eye drops to red, bleary, sleep-deprived eyes
- 3x) Wait, it's working?
- 3y) Decide not to do any more projects that require control systems
- 3z) Wonder why someone doesn't just make a thing that tunes itself

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  - 2) Press Autotune
  - 3) Get a snack
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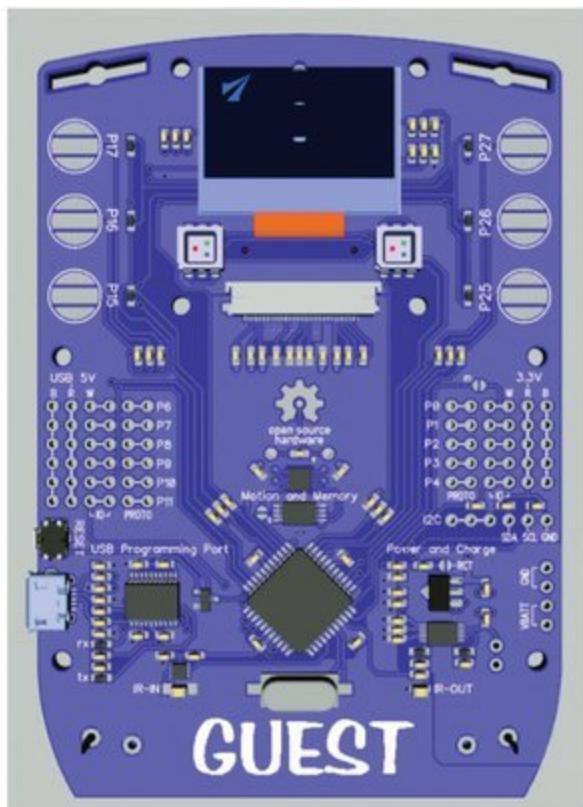
■ BY JON MCPHALEN

# Fun with Charlieplexing

**Back in May, my friend Ken Gracey (CEO of Parallax) tweeted about a project they're working on: a Propeller-powered convention badge for any event that needs one. This was inspired by the success of the DEFCON 22 badge which I had the privilege to help design and write code for. There are lots of tech conventions around the world, yet not everyone has the budget to design custom hardware. This is where Parallax intends to help out. They'll build the badge — you write cool custom code for your venue.**

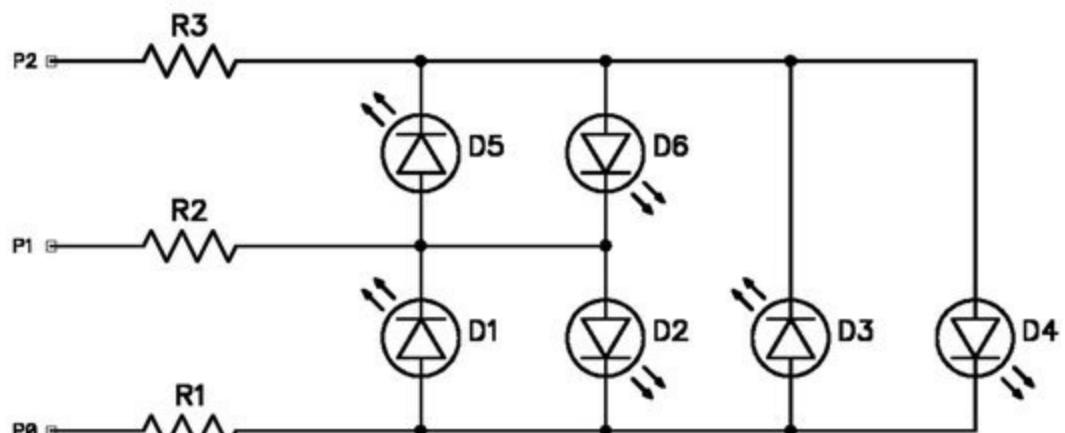
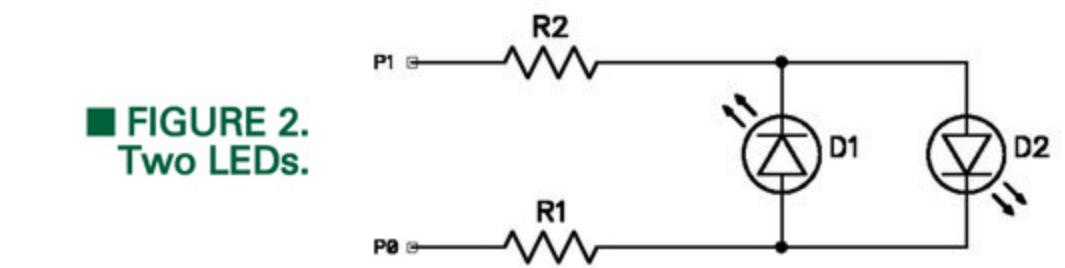
**A**t the time of this writing, the badge design is not completely finalized, though there are a couple LED circuits that won't change. **Figure 1** is a 3D model of the preliminary design. In one section, there are six blue LEDs connected to three resistors and three I/O pins; in another section, the six LEDs of two RGB modules are similarly wired. Wait ... how do we control six LEDs with only three I/O pins? Charlieplexing!

Charlieplexing – named after its inventor, Charlie Allen – is a method of LED control that takes advantage of the processor's ability to manipulate the pin state: a pin can float (input mode); be an output and low; or be an output and high (the term *tri-state* refers to the pin's ability to be in one of three states). We don't often think of the input state



■ FIGURE 1. Hackable badge.

■ FIGURE 2. Two LEDs.



■ FIGURE 3. Six LEDs.

as an output control mechanism, but it's critical to the operation of Charlieplexing. Okay, then, let's start dirt easy with two LEDs (see **Figure 2**).

If we make P0 high and P1 low, current will flow through D1 and light; D2 is reverse-biased and will not light. If we reverse the outputs and make P0 low and P1 high, D2 will light and D1 will be extinguished.

Now, what if we make P0 or P1 an input (i.e., *floating*)? When this happens, the pin is disconnected from the output driver which is like opening a switch. *Both LEDs will be extinguished*, regardless of the state of the other pin. This is key to Charlieplexing.

With this understanding, have a look at **Figure 3** and the corresponding logic table in **Figure 4**. The circuit shows the beauty of the Charlieplex arrangement: With just three I/O pins, we can control up to six LEDs. Getting down to the nitty-gritty, using Charlieplexed connections allows us to control up to  $n * (n - 1)$  LEDs with  $n$  I/O pins. This means four pins could control 12 LEDs, five pins could control 20, and so forth.

As you study the table in **Figure 4**, you'll see that one pair of outputs which is connected across the target LED is set to high (H) and low (L), while the third output is set to the input/floating state (X);

	P2	P1	P0
D1	X	L	H
D2	X	H	L
D3	L	X	H
D4	H	X	L
D5	L	H	X
D6	H	L	X

■ FIGURE 4. Charlieplex control table.

ITEM	DESCRIPTION	SOURCE/PART #	BOM
Propeller Activity Board		Parallax #32910	
Circuit Overlay Board		Parallax #32999	
R1..R3	47 Ohm	Mouser #299-47-RC	
D1..D6	Green, 5mm	Mouser #604-WP7113GD	

this allows us to control the designated LED. Yes, this means that we can only activate one at a time, and for many applications this is fine. For a 1-of-N project, we don't need any special code, just a method to handle which LED is active:

```
pub set_cp_led(n)

dira[CP2..CP0] := %000

case n
0:
    outa[CP2..CP0] := %001
    dira[CP2..CP0] := %011

1:
    outa[CP2..CP0] := %010
    dira[CP2..CP0] := %011

2:
    outa[CP2..CP0] := %001
    dira[CP2..CP0] := %101

3:
    outa[CP2..CP0] := %100
    dira[CP2..CP0] := %101

4:
    outa[CP2..CP0] := %010
    dira[CP2..CP0] := %110

5:
    outa[CP2..CP0] := %100
    dira[CP2..CP0] := %110
```

The method counts on having pin constants CP0 and CP2 defined; these are the LSB (Least Significant Bit) and MSB (Most Significant Bit) control pins of the three-pin group. At the start of the method, we set the direction bits for the group to %000 which disables all outputs. This serves two purposes: 1) It clears the LEDs in the event we pass an invalid LED number; and 2) It prevents ghosting of LEDs when making changes from one to another.

If you look carefully, you'll see that the code in the case structure directly corresponds with the control table. It's a good idea to create such a table when using Charlieplex wiring, and structure the code to follow your table.

This is pretty cool, right? It is, and yet I know you're thinking, "Okay, Jon, that's great, but what happens when I want to have two LEDs on at the same time?" As my friend John B. frequently quips ... no problem, it's just a small matter of programming (SMOP).

So far, we've only used Charlieplex wiring, but the software process of Charlieplexing – like its cousin, multiplexing – is more involved. What we're going to do is loop through a control value that tells us which LEDs are on. For those that are on, we will light them briefly, then move to the next LED.

If we do this fast enough (greater than 50 Hz), the persistence of vision in our retinas will cause the LEDs to appear to be on at the same time.

In most processors, this happens in an interrupt, and for very simple Propeller programs we might even be able to use the timer object to refresh the LEDs on a reasonably fixed schedule. To be on the safe side, however, and keep things general-purpose, I decided to create a stand-alone object.

For the object to work, the LEDs must be wired as in **Figure 3** and the pin passed to the **start()** method is the LSB pin of the three-pin group. After that, everything else takes care of itself. Here are the **start()** and **stop()** methods for the six LED Charlieplex object:

```
pub start(cp0)

stop

cycleticks := (clkfreq / 300) / 6
cog := cognew(charlie_6(cp0), @stack) + 1

return cog

pub stop

if (cog)
    cogstop(cog - 1)
    cog := false

ledbits := %000000
```

It is convention for the **start()** method to call the **stop()** method to ensure everything is clean before launching a cog (as we do here). The **stop()** method will kill the presently running cog, mark it as stopped, and clear the control value (**ledbits**).

The **start()** method sets the timing for LED updates in the global (to the object) variable **cycleticks**. Remember that all timing in the Propeller is done in system ticks. By dividing **clkfreq** (system ticks in one second) by 300, we set the update rate to 300 Hz. Why? In a world filled with

Jon "JonnyMac" McPhalen  
[jon@jonmcphalen.com](mailto:jon@jonmcphalen.com)

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video cameras, this minimizes odd visual artifacts when things are moving. Note that we further divide the timing by six (the number of LEDs we're controlling) to ensure that all LEDs are updated at 300 Hz.

The **cognew** call for a Spin cog requires two parameters: 1) the method that will run it in its own cog; and the hub address of an array used for the cog's stack space. As with launching PASM cogs, **cognew** will return -1 (cog did not launch) to 7, which gets promoted to 0 (false, did not launch) or 1 to 8 when everything launched normally.

The Charlieplex process is simple enough that we can run it in a Spin cog without resorting to assembly, so long as we keep the application clock frequency at 20 MHz or higher (more on this later). Here's the method that runs in its own cog:

```
pri charlie_6(cp0) | cp2, t, cycle

cp2 := cp0 + 2

t := cnt
repeat
    repeat cycle from 0 to 5
        dira[cp2..cp0] := %000
        if (ledbits & (1 << cycle))
            case cycle
                0:
                    outa[cp2..cp0] := %001
                    dira[cp2..cp0] := %011

                1:
                    outa[cp2..cp0] := %010
                    dira[cp2..cp0] := %011

                2:
                    outa[cp2..cp0] := %001
                    dira[cp2..cp0] := %101

                3:
                    outa[cp2..cp0] := %100
                    dira[cp2..cp0] := %101

                4:
                    outa[cp2..cp0] := %010
                    dira[cp2..cp0] := %110
```

```
5:
    outa[cp2..cp0] := %100
    dira[cp2..cp0] := %110

    waitcnt(t += cycleticks)
```

This method – as the **start()** method did earlier – expects to receive the base pin of the three-pin group as a parameter. A local variable *cp2* is calculated for the MSB pin of the control group. Variable *t* is used for timing the synchronized inner loop; this will run at the rate set by *cycleticks* that was set up in the **start()** method.

Inside the primary **repeat** loop, a variable called *cycle* iterates from 0 to 5; this is used to designate which LED we're working with at the moment. As we did before, the control pins are defaulted to inputs to disable everything. The next step is to test our control value based on *cycle* using a temporary mask. If the corresponding bit in *ledbits* is 1, we will activate the LED. This goes on while the cog is running at a rate that fools our eyes into thinking multiple LEDs are on at the same time.

To control the LEDs, we need to manipulate *ledbits*. Here are two methods to do that:

```
pub set_led(n, state)

if ((n => 0) and (n =< 5))
    if (state)
        ledbits |= 1 << n
    else
        ledbits &= !(1 << n)

pub set_all(bits)

ledbits := bits & %111111
```

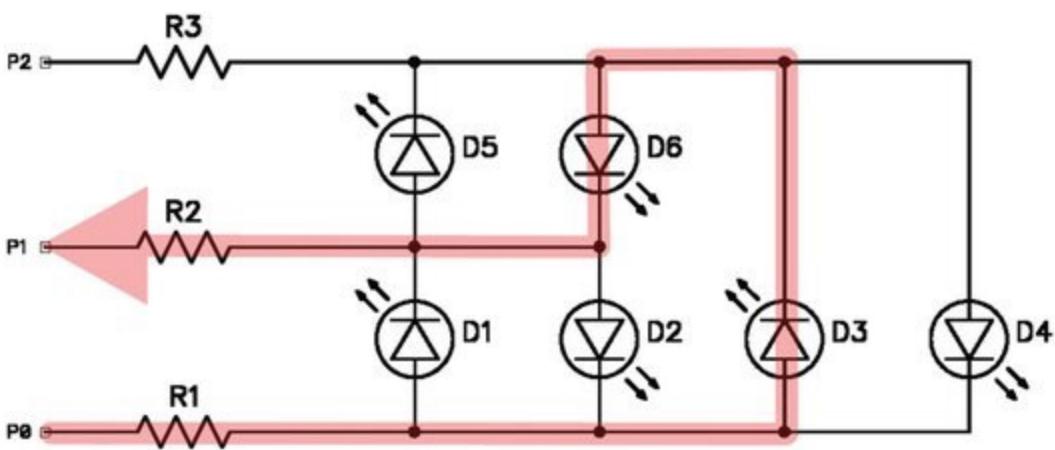
The first method allows control of a single LED. We pass the LED number (0 to 5) and a state value, where any non-zero state value is accepted as on. If the state is not 0, the corresponding bit is set to 1 (on); if the state is 0, the corresponding bit is set to 0 (off).

For cases where we want to treat all LEDs as a single value, the **set\_leds()** method takes care of that.

Inside the demo program, there are two methods that demonstrate single- and multi-LED access. The first is – you guessed it – a six output Larson scanner. It would be heresy to have a strip of LEDs and not program them to do a Larson scan, right? This one can even be configured:

```
pub run_larson(cycles, ms) | n

repeat cycles
    repeat n from 0 to 4
        leds.set_led(n, true)
        time.pause(ms)
```



■ FIGURE 5. Bad path.

```
leds.set_led(n, false)
repeat n from 5 to 1
  leds.set_led(n, true)
  time.pause(ms)
  leds.set_led(n, false)
```

The first parameter of ***run\_larson()*** is the number of back and forth cycles to run; the second is the delay time for each LED. For a one second cycle, the delay timing is set to 100 ms by the caller.

The second method is a simple counter that uses all six LEDs:

```
pub run_counter(ms) | n

repeat n from %111111 to %000000
  leds.set_all(n)
  time.pause(ms)
```

No, it's not terribly exciting, but it does, in fact, verify that we can have up to six LEDs [appear to] be on at the same time.

There you have it: six LEDs for the cost of three pins and three resistors. There are a couple things to note

when using Charlieplexed LEDs. When using the simple circuit shown in **Figure 3**, the LEDs should be of the same type and forward voltage. If you're going to mix LEDs, remove the resistors shown and replace each LED with an appropriate LED/resistor combination.

Another thing that one must watch for is the resistor values. Have a look at **Figure 5**; what this illustrates is the possibility of lighting multiple LEDs under the right conditions. When we light D1 (P0 high, P1 low, P2 floating), there can be a secondary path through D3 and D6 as shown.

This can happen if the combined forward voltage of the LEDs is lower than the output voltage of the controller, and the resistors are so small that enough current can flow to light both LEDs — though they won't be as bright as the target LED.

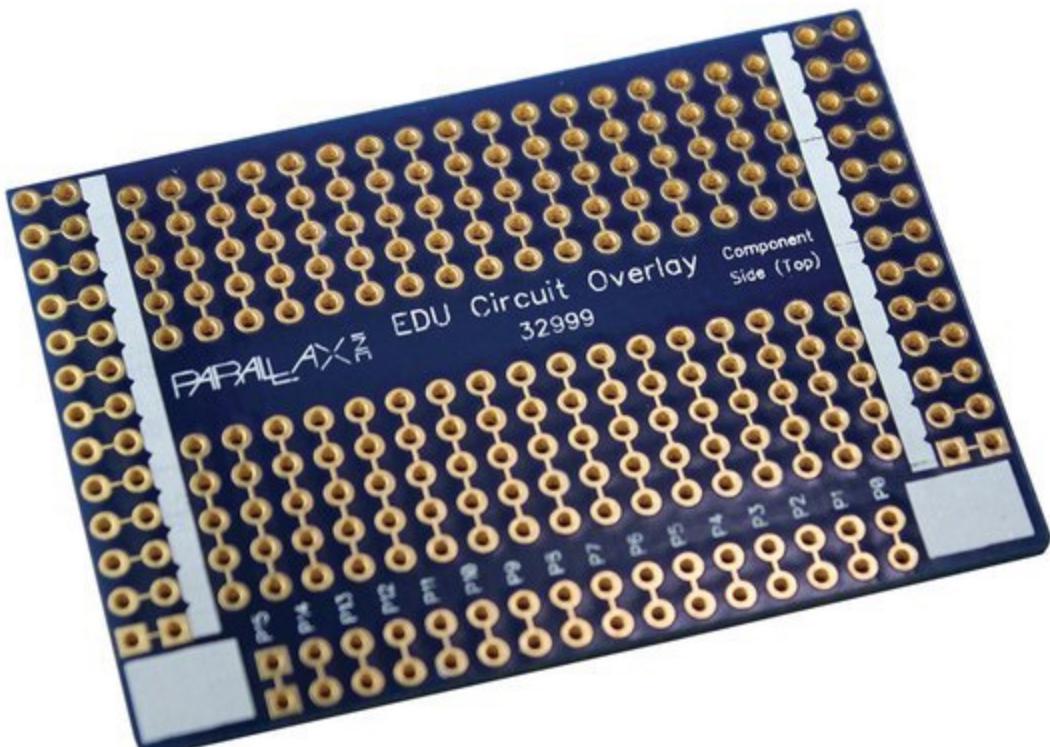
For my circuit, this isn't a problem because the forward voltage of each LED is about two volts; there is no way to light two of these LEDs in series with a 3.3V micro. That said, if I moved this circuit to a 5V micro, I would have to check the resistor values.

Finally, I mentioned earlier that the Spin driver will run down to a clock speed of 20 MHz (PLL = 4x). We can speed things up by converting the Charlieplex operations to PASM; this will allow us to run all the way down to 5 MHz (PLL = 1x). This might be helpful when using the Charlieplex circuit in a battery powered application.

I've included a duplicate of the demo code which uses the PASM version at the article link. Those of you that are starting to make the move from Spin to PASM will find the code interesting. The PASM is very simple, and a near direct match of the Spin code.

## Lock It Down!

If you're like me, you have solderless breadboards



■ FIGURE 6. Overlay PCB.



■ FIGURE 7. Overlay on PAB.

with parts in them that never come out. In my case, many of these are in the form of Propeller Activity boards (PABs). My friends at Parallax have introduced a new product that lets me keep my circuit and free up my Activity boards. It's called the Circuit Overlay Board (**Figure 6**), and it's compatible with the Activity board and the various "Boards of Education" from Parallax. Plus, it's less than six dollars!

You can see the overlay board in action in **Figure 7**. On the left is an Activity board with the Charlieplexing circuit installed. On the right is another with the same circuit soldered into an overlay PCB (printed circuit board). Like any shield, I can pop this in and out at my leisure — the PAB breadboard is no longer locked up with a favorite circuit.

To make matters even better, Parallax has released the DipTrace design files for the overlay PCB. The release of these files will facilitate — and I hope encourage — the creation of shields for the Propeller Activity board. I've certainly got plans. Will you join me?

## Timer Update

Every day, I seem to find another use for my timer

object (covered in the June 2015 issue) and find reasons to add features. A note from a *Nuts & Volts* subscriber reminded me: *Let others review your code* — especially the code you're really in love with. And, no, I'm not ashamed to say that I'm in love with some of my code. Real men admit such things.

A gentleman named Dennis Page kindly pointed out that the *mark()* method was unnecessarily recalculating values; these calculations take time, hence affect the speed of the method. He was absolutely right. I had been so close to the code that I looked right past this inefficiency. Thank you, Dennis, for pointing this out. The updated object is used by the Charlieplexing demos, so do save it to your Library folder.

Until next time, keep spinning and winning with the Propeller! **NV**


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The Gooseneck™ now available from ServoCity is a little trail-wheel robot kit that glides effortlessly across the floor. The 2.975" orange skate wheels are each driven by a 195 RPM 3V-12V precision planetary gearmotor. The "truck-bed" style chassis is ideal for battery storage, electronics, or for hauling things around. The chassis is almost entirely snap-together, requiring only a 7/64" hex key for assembly. The chassis plates incorporate the 0.770" Actobotics hub pattern, allowing for easy attachment and customization using other Actobotics components. The protruding "Gooseneck" piece provides a base for a robotic arm, gripper kit, scoop, or other custom attachment. Price is \$89.99.



## ACTOBOTICS GEARMOTOR POWER INPUT BOARDS

The gearmotor power connector boards also now available from ServoCity add versatility to any gearmotor. These boards simply slide over the motor terminals and solder in place. The pre-installed .100" spacing row pins allow plug-and-play connectivity to several different plug styles (JST, Rx battery connector, male servo connector). The plug-in makes switching polarity, swapping motors, and reconfiguring a robot without firing up the soldering iron quick and easy. Each board has multiple holes which can be utilized to run additional wires to the motor or to daisy-chain multiple motors. It is sold with 90 degree header pins pre-soldered to the board. Prices start at \$0.69/each.

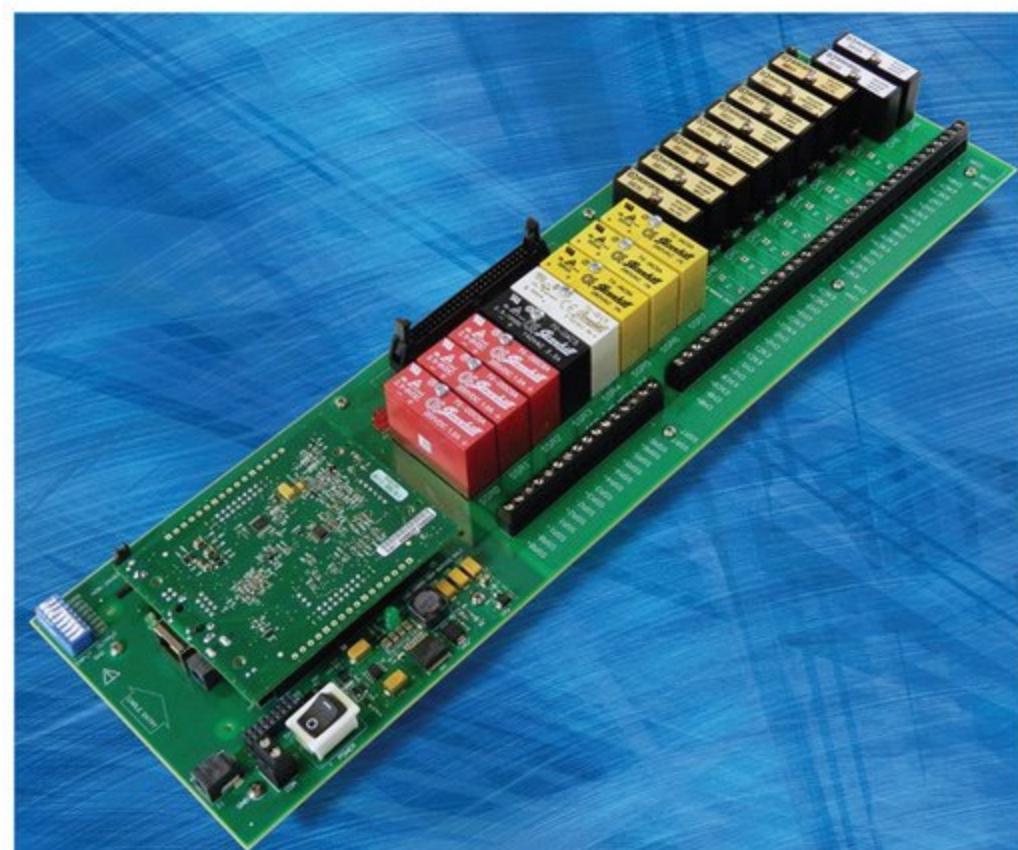


## HIGH SPEED CONDITIONED MEASUREMENTS WITH **CHANNEL-to-CHANNEL ISOLATION**

Measurement Computing Corporation announces the release of the SC-1608 series of USB and Ethernet data acquisition devices. The SC-1608 series features analog signal conditioning, allowing customers to easily measure voltage, thermocouple, RTD, strain, frequency, and current. Isolated analog output and solid-state relays make it an ideal platform for systems needing flexible conditioning and low cost per channel. The SC-1608 series is priced starting from \$999.

There are four devices in the SC-1608 series with sample rates up to 500 kS/s. Each device accommodates up to eight 8B isolated analog signal conditioning modules and eight solid-state

For more information, contact:  
**ServoCity**  
[www.servocity.com](http://www.servocity.com)



relay modules. Up to two isolated analog outputs are available on some models. Signal conditioning modules are sold separately.

Microsoft Windows software options for the SC-1608 include DAQami and TracerDAQ to display and log data, along with comprehensive support for C, C++, C#, Visual Basic, and Visual Basic .NET. Support is also included for DASYLab and NI LabVIEW. UL for Android provides programming support for Android devices. Open source Linux drivers are also available.

For more information, contact:  
**Measurement Computing**  
[www.mccdaq.com](http://www.mccdaq.com)

## HIGH SENSITIVITY CURRENT PROBES

Saelig Company, Inc., announces the availability of the CP030A (50 MHz) and CP031A (100 MHz) high sensitivity current probes from Teledyne LeCroy. Providing sensitivity down to 1 mA/div, users can now measure currents from millamps right up to a peak current of 50 amps, all with the same probe. This represents ten times the sensitivity of previous models, and allows for more precise low current measurements on most Teledyne LeCroy oscilloscopes. When used with Teledyne LeCroy's 12-bit resolution HDO high definition oscilloscopes, users can obtain highly accurate, low current waveforms for improved debug and analysis capabilities.

The CP030A and CP031A probes expand the capabilities of Teledyne LeCroy current measurement products to additional applications by providing the ability to measure and analyze very low current waveforms. The probe's small jaws are designed to measure

*Continued on page 69*

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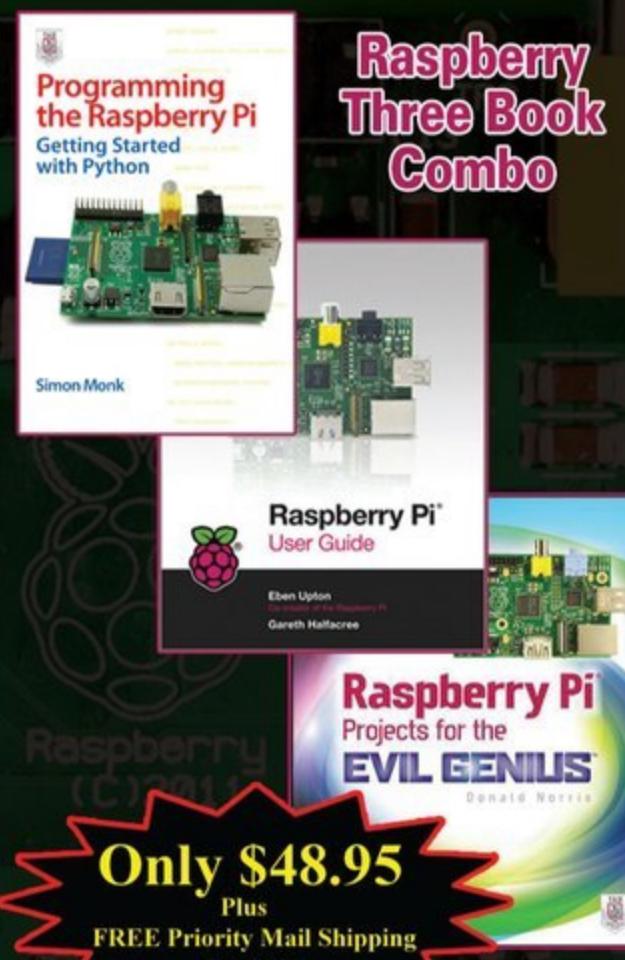
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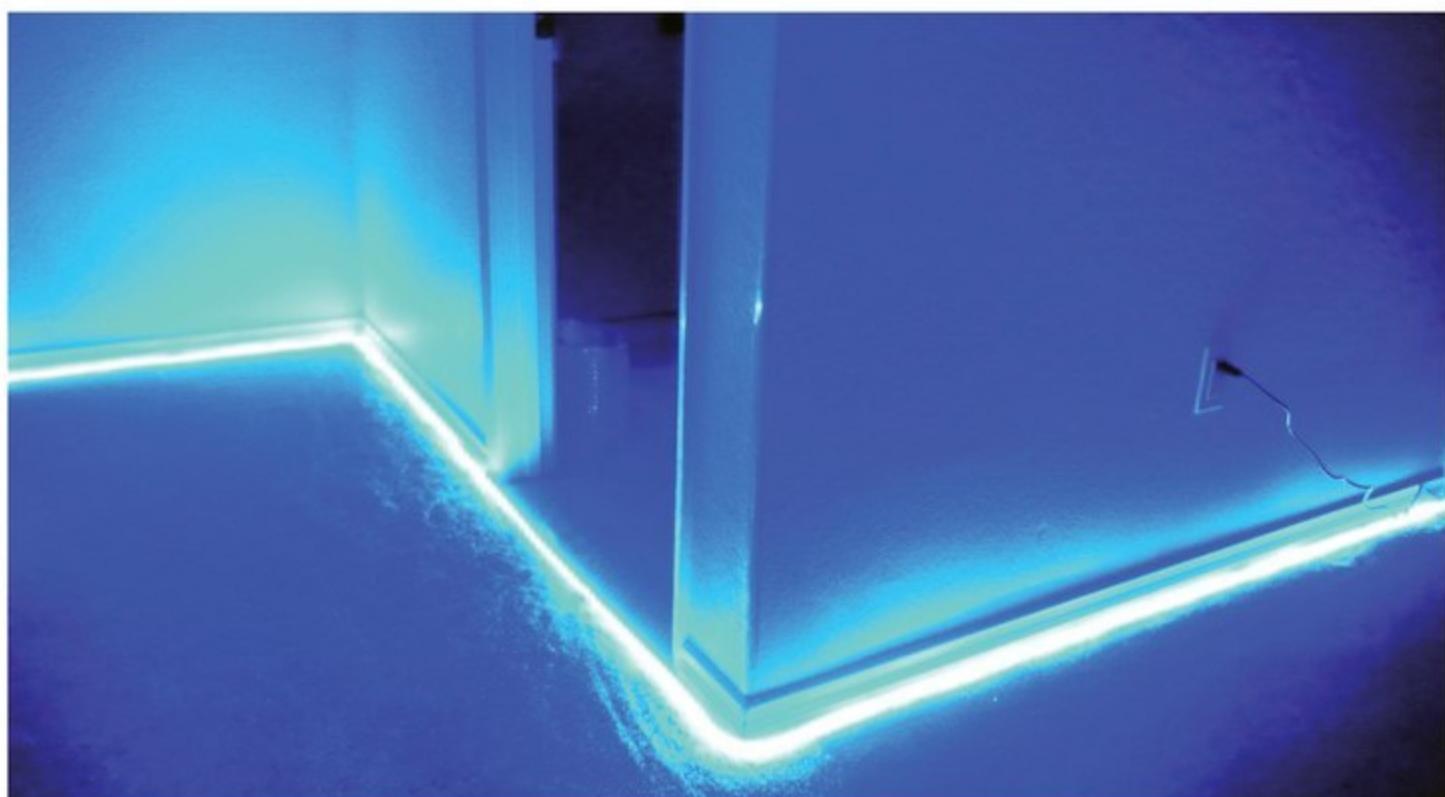
**Designtronics** Inc.



# Motion Triggered Plane Aisle NIGHT LIGHTING

By Geoff Clark  
nv@beamir.com

Post comments on this article and find any associated files and/or downloads at [www.nutsvolts.com/index.php?/magazine/article/august2015\\_clark](http://www.nutsvolts.com/index.php?/magazine/article/august2015_clark).



Reading through parts catalogs is a pleasure which being a subscriber to *Nuts & Volts*, you can probably relate to. As I leafed through the M. P. Jones & Associates (MPJA) offerings recently, a motion sensor caught my eye because it was only \$3.95. The cheapest at a major distributor is many times that. It made me think of how to automate some of my home lighting, because I am the stereotypical dad that walks the house at night snapping off lights left on by the non-electric-bill-paying residents and muttering under my breath. A few pages later was a five meter roll of blue LEDs that I noted was down to just over a dollar a foot. LEDs for illumination were unknown a few years ago, and now look. They are affordable, and you just peel off the backing and stick them anywhere. Yes! I could have cool blue strip lighting along the hallways of my home – just like the fancy ones that light up an airplane aisle in case of emergency. Plus, there's no extra wiring for a wall switch (which everyone but myself would ignore anyway) because just walking by turns it on!



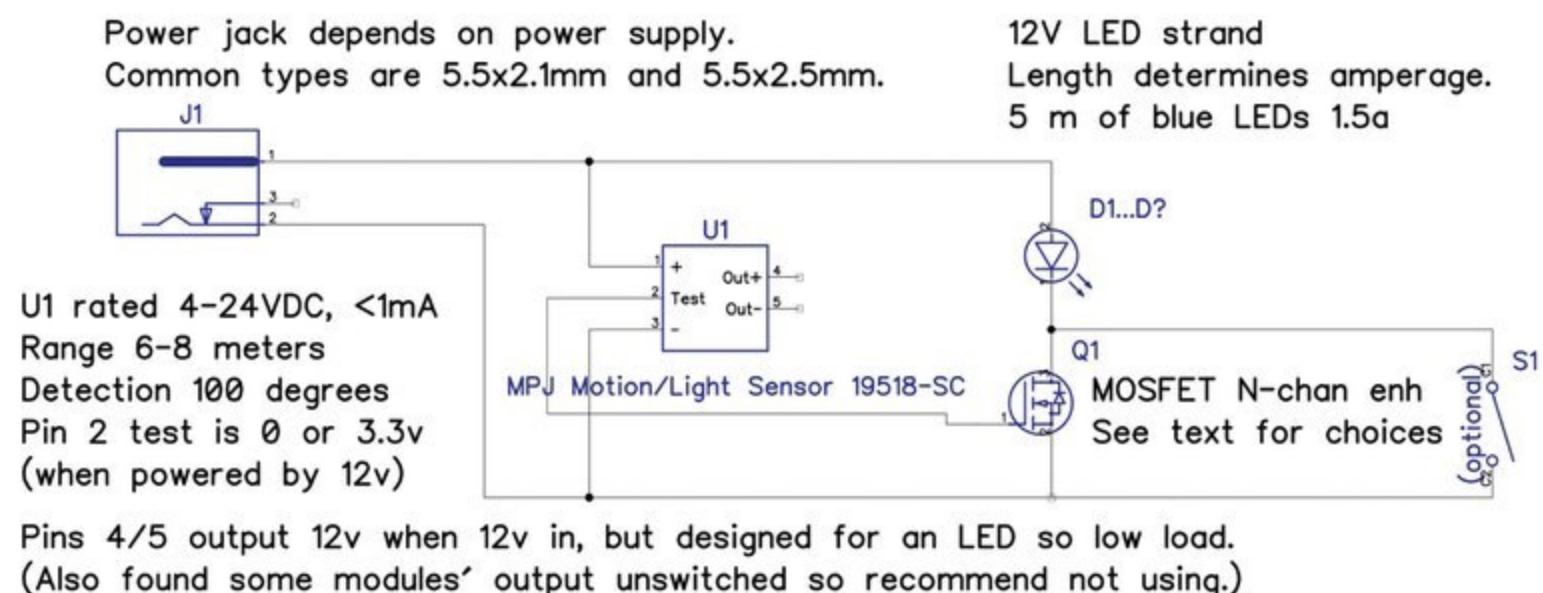
**W**hat else would I need? A light sensor so it didn't turn on during the day? No, it's built in and adjustable! A microprocessor to add a delay before turning off? No, the delay is built in and adjustable! Sensitivity? Adjustable. five volt regulator? No, this \$3.95 bargain can run off the same 12 volt supply that powers the LED strip. Speaking of which, a 12 volt, 2.5 amp supply is just \$5.95 in the same catalog!

## Assembly

**Figure 1** shows how to hook everything up. The only component not available at [mpja.com](http://mpja.com) is the MOSFET that drives the LED string controlled by the 3.3V "test" output of the motion sensor. Go to the supplier of your choice and use these parameters: MOSFET (obviously), N-channel enhanced, single, through-hole (avoids soldering), continuous drain current at least 2.5A (the capacity of the power supply), drain-source breakdown voltage over 12V (select over 20V for safety), gate threshold voltage under 3V, and resistance (RDS on) less than 0.16 ohms (because we want less than one watt of heating). I found 516 in stock, many under a dollar. Sort by price and start double-checking the datasheets. I used an MTP10N10EL which I don't recommend because it is obsolete, but I had it on hand. Its RDS on is typically 0.17 ohms, so at 1.5 amps (full blue LED string), I expect 0.38 watts ( $W = I^2R$ ).

MOSFET N-chan enh  
DMN3150L is 30vDS, 1.4vG, 3.8aD.  
.054 RDS On max x 1.5a x 1.5a = .12W  
At 90degC/W = 11 degC rise

■ FIGURE 1.



Multiply by 100°C/W (thermal resistance junction-to-ambient on the datasheet) means a 38°C rise, so a small heatsink should be considered. Your MOSFET will do much better. Order several because your microcontrollers always need to drive loads.

The sensor in **Figure 2** is wired with 22 gauge stranded and ready to go. Notice how the wires are soldered to a header (see Parts List), so the motion sensor can be easily unplugged and replaced if you accidentally short it out. On a related subject, I suggest *not* using a metal screwdriver and a shaky hand to adjust the pots when the power is on. Insert the MOSFET last because it is static sensitive.

Now, let's pimp your ride. A few more cheap components will keep your home's resale value high, starting with an unobtrusive enclosure for \$1.95 (see Parts

ITEM	DESCRIPTION	PART #	COST	PARTS LIST
(or)	12V 2.5A power supply (uses 5.5 x 2.1)	30226PS	\$5.95	
J1	12V 2.5A power supply (uses 5.5 x 2.1)	30201PS	\$5.95	
(or)	Cord for either supply (don't forget!)	15447CB	\$1.25	
(or)	5.5 x 2.1 mm jack chassis mount	18549PL	\$1.49	
(or)	2.5 x 2.1 cable jack	19160PL	\$0.99	
U1	PIR motion detector w/light sensor	31227SC	\$3.95	
D1	5M Blue LED strip 12V	19441OP	\$14.95	
(or)	5M White LED strip 12V	19434OP	\$14.95	
(or)	5M White LED strip 12V indoor only	31192OP	\$9.95	
S1 optional	Toggle switch	12216SW	\$0.95	
Q1	MOSFET (see text)			
Optional	Header connector 10-pin (cut in half, ruin a pin but make a five-pin and a three-pin connector, or two four-pins)	31053HC	\$0.30	
Optional	Black plastic cabinet 3 x 2 x 1.1	15522BX	\$1.95	
Optional	5.5 x 2.1 mm plug with screw terminals so LEDs can plug in	19452PL	\$0.89	
Optional	Another chassis jack like J1 to plug in LEDs			
All items available from <a href="http://mpja.com">mpja.com</a>	12V 750 mA power supply for shorter strings	31926PD	\$3.95	

It looks like I am an employee of MPJA, but I'm not. Compare prices for yourself. Note some parts may be removed from hopefully working equipment.

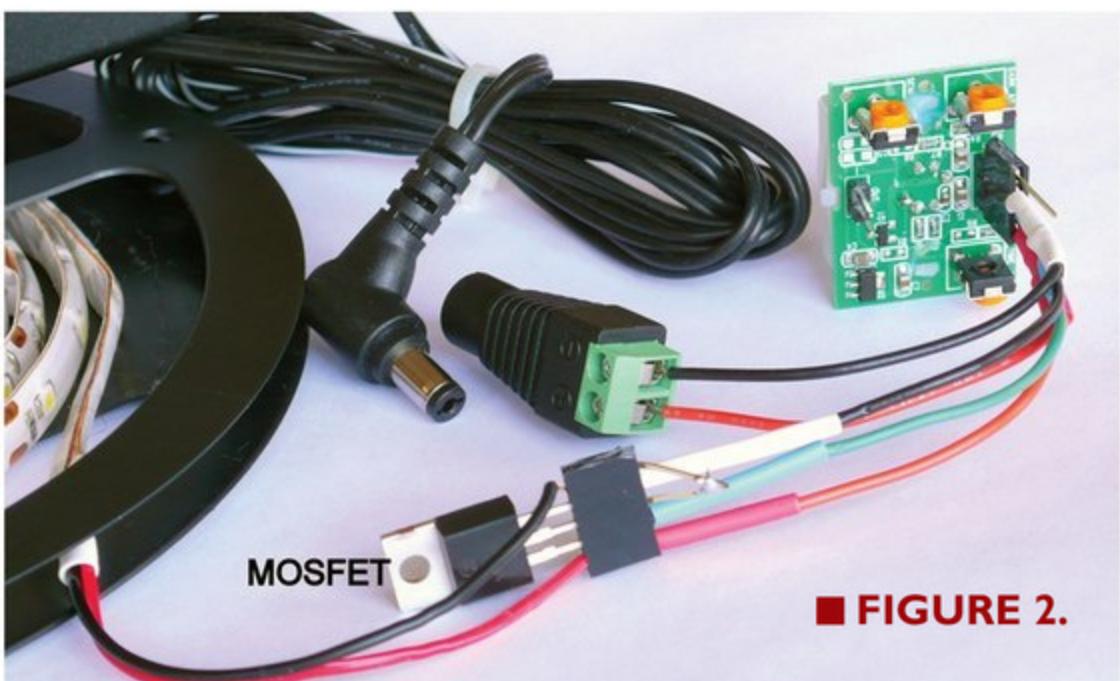
## Five Meters can Make More than One

The LED strip can be cut every three inches (it's marked), but realistically you will want larger pieces. Suppose you want one meter (three feet) for accent lighting a fish tank (unless it would drive the fish crazy). If five meters (blue or white) uses 1.5 amps, then one meter needs about a 350 mA supply. The motion sensor uses a negligible 1 mA, so a \$3 wall wart will suffice.

Cut underneath the PVC and peel back to solder leads to the top (**Figure A**). Unintuitively, the bottom doesn't solder well. Blob on silicone sealant to protect.

- If your closet doesn't have a light, it should. If there is a light, it's burning right now because the door is shut and no one knows it's on. Put LEDs around the upper molding. Aim the motion detector at the doorway.

- A short blue bathroom nightlight won't hurt your eyes.
- Under-cabinet lighting makes your kitchen counters pop.
- PVC coated LED strips are weatherproof, so deck out your deck, patios, and porches. Just make sure the rest of the circuit is protected (MPJA has sealed enclosures, too).
- Enhance indoor or outdoor Halloween or holiday decorations.



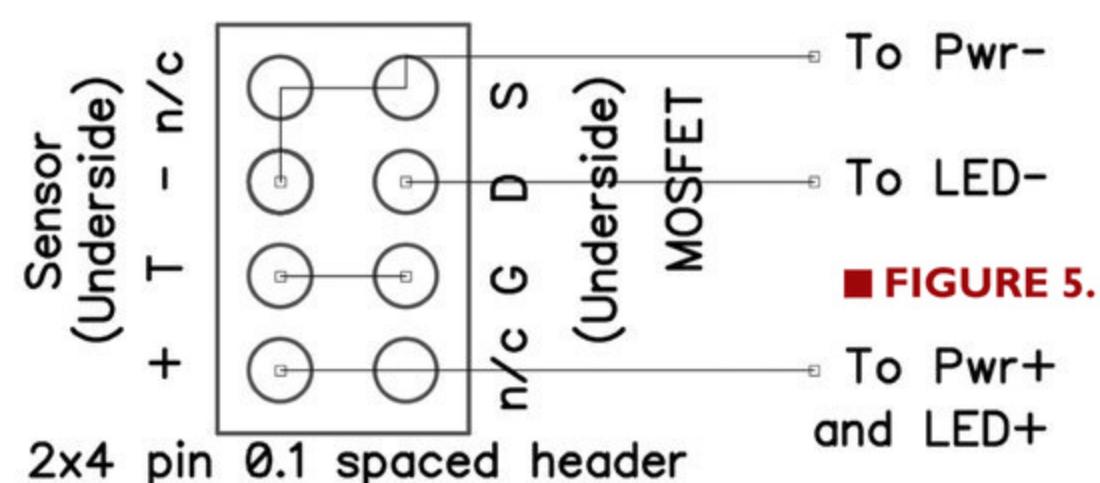
**■ FIGURE 2.**



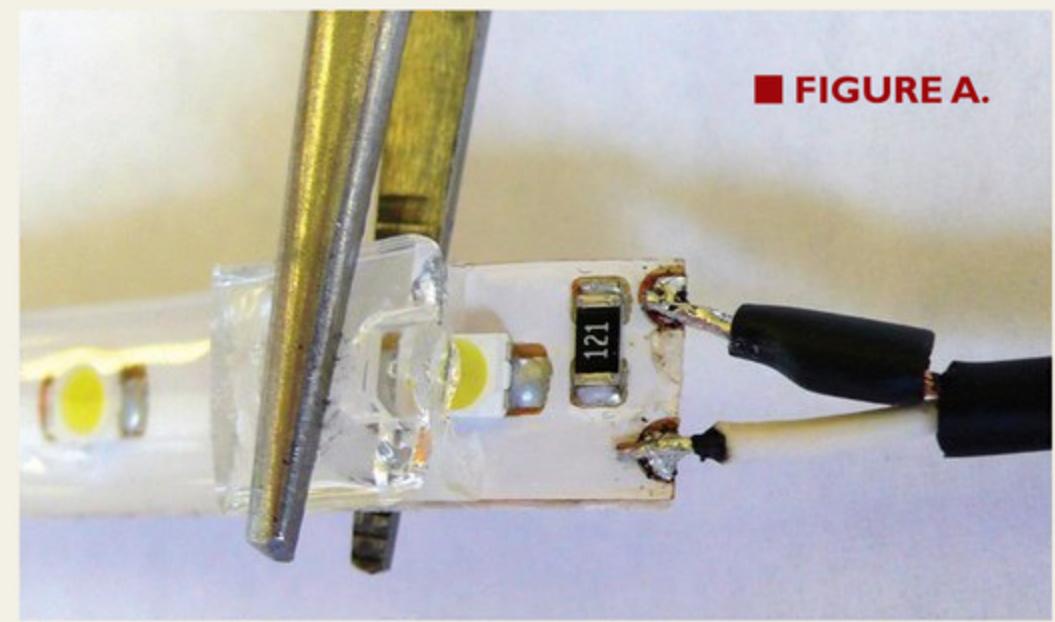
**■ FIGURE 3.**



**■ FIGURE 4.**



**■ FIGURE 5.**



**■ FIGURE A.**

List). Drill a one inch hole for the sensor and (optionally) three smaller holes for the adjustment pots. **Figure 3** shows how using chassis jacks (see optional Parts) for power and the LEDs looks professional, but I can't recommend using identical jacks for different functions — no matter how well labeled — if you are making this for someone else. (Just my experience.) Also, this configuration works better with two four-pin headers next to each other, wired as in **Figure 4**.

## Shine On

Adhere the LEDs. Your aisle lighting is ready for take-off (**Figure 5**). Plug the unit in, wait for dark, and watch your kid's faces as they approach for the first time and the strip pops on magically! Tape over existing light switches to break carbon-footprint-insensitive humans of their wasteful habits (install manual switch S1 only if threatened). One meter of white LEDs produces 660 lumens — more than a 40 watt incandescent.

Even compared to CFLs, LEDs are twice as efficient and last six times longer. Go green! **NV**



By Bob Fischer  
The Antenna Sculptor

Post comments on this article and find any associated files and/or downloads at [www.nutsvolts.com/index.php?/magazine/article/august2015\\_Fischer](http://www.nutsvolts.com/index.php?/magazine/article/august2015_Fischer).

My father gave me a crystal radio set when I was around eight or nine years old. It was truly amazing! Just a few electronic components, an earphone, and two short wires with alligator clips.

Without a battery or any other source of power, this magical little device would pick up radio stations and play them through the earphone. All I had to do was attach one of the alligator clips to an "antenna."

# BUILD A 50 MHz DIPOLE OUT OF CRUTCHES *(Yep, crutches!)*



soon discovered that most metallic objects a few feet in length made good enough antennas to bring in the closest AM station. Attaching the second alligator clip to metal that was "grounded" or in contact with the earth improved signal strength and brought in weaker signals.

Those childhood "experiments" soon taught me that some metal objects were much better antennas than others, and that bigger metal was not always better. I have never forgotten the anticipation and excitement of attaching alligator clips to new materials and then hearing the results through the earphone.

I was hooked. The fascination of signaling through space without wires would become my primary hobby for the next half century. While writing this article, I realized I have actually been experimenting with antennas since I was in elementary school.

Later in life, I studied electronics and then electrical engineering. I learned about resonance and how radio frequencies have electrical wavelengths. Around 1969, I got my first ham radio license.

Over the last 45 years, I have built dipoles, ground planes, J-poles, quads, yagis, quagis, delta loops, and long wires. In addition to the traditional copper wire, I have cobbled them together using EMT and rigid aluminum conduit; copper, aluminum, and stainless steel tubing; brass welding rods; and even barbed wire. I have also used antenna tuners to load up bedsprings, fences, house wiring, abandoned telephone line, umbrellas, farm wagons, aluminum gutters, and tin roofs.

Just as other sculptors are blessed with the vision to see their works of art hidden in wood and marble, I have developed the ability to see antennas hidden in metal.



**■ FIGURE 1.**

After working with antennas for a while, I believe most everyone can probably develop an eye for dimensions that are quarter-wave multiples of their favorite frequencies.

A couple of months ago, my wife had an accident that injured her right foot. X-rays confirmed bones were broken, and an orthopedic surgeon sent her home with a cast and a set of shiny, new, adjustable aluminum crutches.

When all the medical excitement was over, I had time to take a closer look at her hobbling around on those crutches. That's when I spotted the six-meter antenna hidden in them. A few minutes with the tape measure not only confirmed the 6M antenna, but also discovered a 4M dipole. All I needed to do was get the wife healed up and the crutches would be mine.

Eventually, the broken bones did mend and the crutches became surplus to her. That made them prime material for a novel antenna that would also become an eye-catching conversation piece.

My particular set of crutches happen to be rated for 300 pounds. Each crutch has two separate adjustments. The upper section has three settings 5-1/2 inches and 6 inches apart. The lower section has 13 positions in one inch increments. Refer to **Figure 1**.

When everything on one crutch is extended to its maximum length, it measures approximately 60 inches. Certainly long enough to make a 112 inch 6M dipole!

Compressing all the adjustments reduces the same crutch to 36-1/2 inches. Plugging these dimensions into the old standby dipole formula ( $468/\text{MHz} = \text{inches}$ ) indicates half-wave resonances from about 47 MHz to 78 MHz. Great! Now, all I needed to do was find a way to put the two crutches together and feed them with coax.

<u>QTY</u>	<u>ITEM</u>
2	Adult size aluminum crutches
6"	3/4" ASTM D 2241 PVC pipe (The ID of schedule 40 PVC was too small to work on my crutches.)
1	1-1/2" Schedule 40 PVC tee
2	1-1/2" x 3/4" PVC reducing bushings
2	#8-32 x 3" Machine screws
6	#8-32 Hex nuts
4	#8-32 Flat washers
2	#8-32 Star lock washers
2	#8 Crimp type ring connectors suitable for use with the size coax cable used to feed the antenna

## PARTS LIST

1.8									
1.7							*		
1.6									
1.5				*					
1.4									
1.3			*						
1.2		*			*				
1.1	*	*	*						
SWR1									
MHz	50.0	50.5	51.0	51.5	52.0	52.5	53.0	53.5	54.0

■ FIGURE 5.

My crutches are sold by Walgreens (Item 276734) for around \$46. However, I have found that crutches must be surplus for a lot of other people. Since starting this project, I have seen several sets at flea markets for around \$2. That's definitely the place to buy this antenna hardware.

I found the bottom (foot) of each crutch was almost the perfect size for a slip-fit inside 3/4 inch ASTM D 2241 PVC pipe. The feet had already been drilled with 1/8 inch holes. Reaming the holes just a little allowed #8-32 screws to pass through.

The holes turned out to be perfect for securing the crutches to the pipe, but the 3/4 inch thin wall PVC looked a little light for supporting the weight of extended crutches. A 1-1/2 inch schedule 40 PVC tee and two 3/4-1-1/2 reducing bushings appeared to be just the right size for reinforcing the lighter 3/4 inch PVC. Check out **Figure 2** and **Figure 3**.

Home Depot had all the PVC parts and the hardware in stock for less than \$11. Total cost of my project would have been around \$12 if I had bought my crutches at the flea market.

Initially, I bought #8-32 x 3 inch machine screws long enough to pass all the way through the tee, fasten the crutches, and terminate the RG-58 coax. As I was drilling the PVC, I noticed #8-32 nuts would fit in the space between the crutch foot and the 3/4 inch PVC, so I decided to drill holes in only one side of the tee and the short 3/4 inch sleeve. I believe this design provides better electrical connections and also increases structural rigidity.

I built the antenna (**Figure 4**) in just over two hours after I had collected all the materials. The only tools I used



■ FIGURE 2.

■ FIGURE 3.

were a hacksaw, screwdriver, drill bit, and pair of long nose pliers.

When the completed antenna was up in the air on top of a short joint of 1-1/2 inch schedule 40 rigid conduit, the dipole needed to be shortened to 98 inches for an SWR of 1.1 from 50 to 51 MHz (**Figure 5**).

I'm certain this novel antenna would never survive high winds or ice loads, but it was not built with permanent installation in mind. I think the best uses for these crutches are teaching antenna resonance, getting attention at hamfests, and starting conversations about emergency communications at public venues promoting ham radio. **NV**

Robert Fischer WB8BEL is a physicist and electrical engineer. He specializes in process instrumentation and maintenance reliability. He can be reached at BobFischer@FischerTechnical.com.



■ FIGURE 4.

*The Arduino rides the rails ...*

# MICROPROCESSORS AND MODEL TRAINS MEET

# HEAD ON!

By Bob Fink

Post comments on this article and find any associated files and/or downloads at [www.nutsvolts.com/index.php?/magazine/article/august2015\\_Fink](http://www.nutsvolts.com/index.php?/magazine/article/august2015_Fink).



I've been blessed for many years with having two great hobbies. One is usually enough but when you can use one as a tool to enhance the other, that's pure fun. I've been a scale model railroader for many years, and when PCs and then microcontrollers came along, I found that there are many ways to combine them.

Let me share with you one of the ways I've combined two train "needs" into one computer application.

There have been many hardware and software approaches to getting model railroad grade crossing flashers to operate. All have worked, but they usually just had the flashers come on at one side and then off at the other. Why don't we use the sophistication of a processor like the Arduino to do a more realistic job? And while we are at it, why don't we have the little machine measure and report the train's scale speed as it passes by?



## Let's Get Real

If you have ever sat at a railroad crossing, you may have noticed that the flashers go off instantly when the last car of the train leaves the crossing. They come on when the train is a good distance away (prescribed by state and federal law), and work from either direction. With an extra pair of sensors, we can have that realistic action. With four sensors, we have enough tools to do a timing job to calculate the scale speed of the train's passage from either direction.

Most of the jobs on a model railroad involve sensing the presence of a train. Traditionally, it has been done by sensing current flow through the track, or by the older method of optical or mechanical sensors. The advent of microcontrollers has revived a simple use of a light dependent resistor (LDR), or photosensor. I have also used phototransistors (they are presented here as an alternative).

In either case, we place the sensor in a drilled hole in the center of the track, connect it through a simple voltage divider to an analog input pin, and rely on the Arduino's built-in analog-to-digital converter (ADC) to yield a digital light level number.

**Figure 1** shows the placement of the four sensors at the crossing. The "Speedometer Distance" shown needs to be the same between the two sensors on either side of the crossing, and must be accurately measured for inclusion in the software sketch.

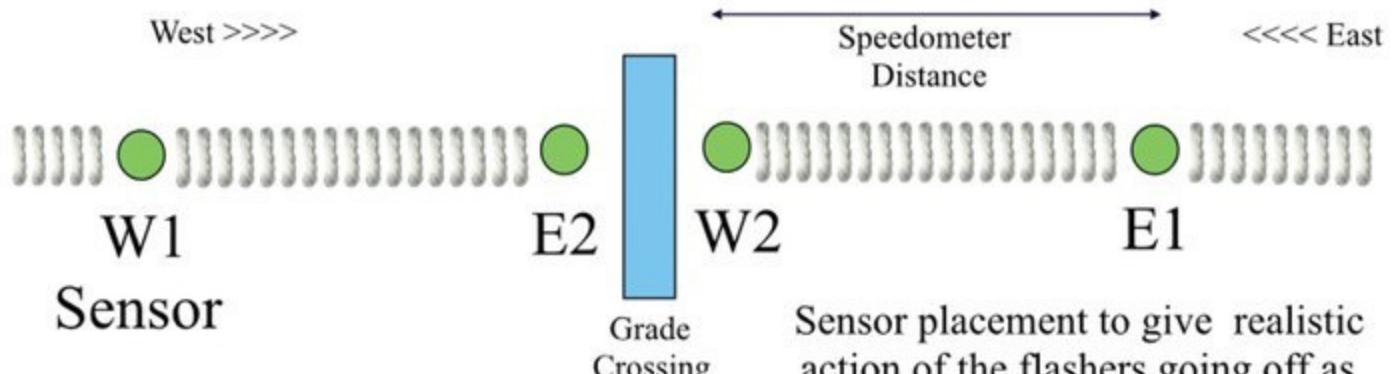
## Calibration is the First Step

With any optical sensor, we need to find that value of digital data the processor produces when it has gone from

### ITEM

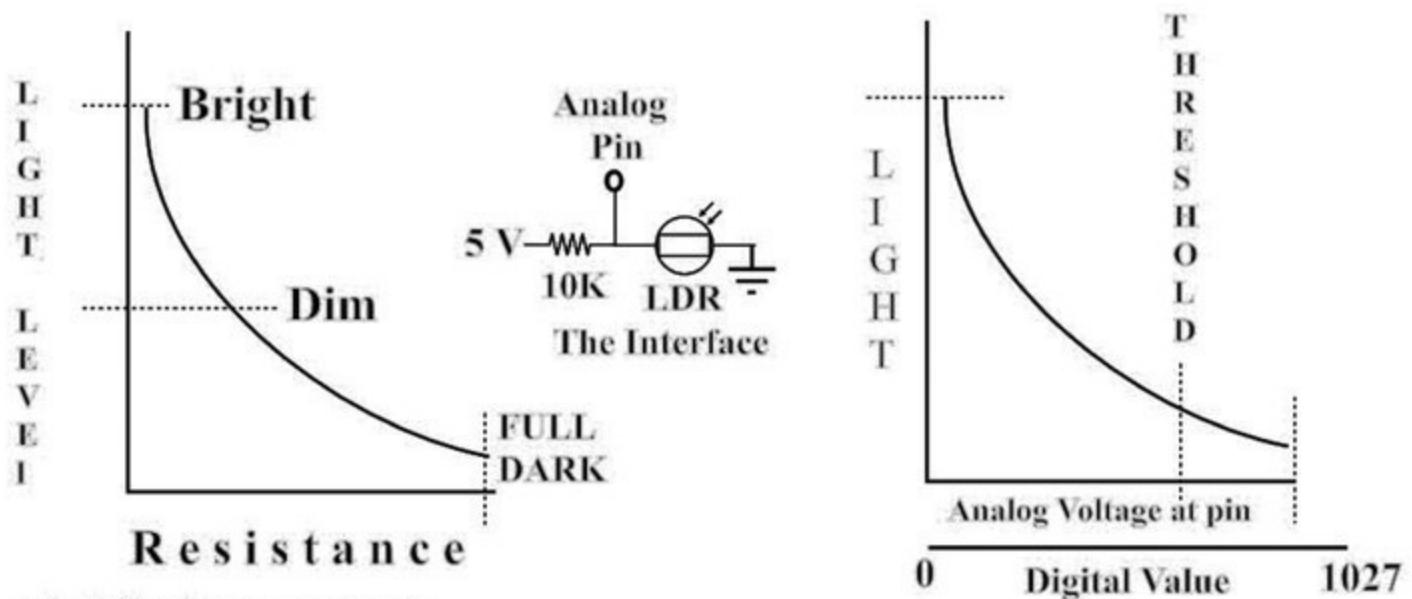
Crossing flashers and a speedometer  
Photoresistors (Catalog #PRE-24)  
Phototransistors (Catalog #PTR-2)  
LCD displays  
Arduino boards (many sources)  
20 x 4 LCD display

Scale Factors: G gauge 24 (varies); O scale 48; S scale 64; HO 87; N 148; Z 220.



Sensor placement to give realistic action of the flashers going off as train clears the crossing.  
Speedometer distance is accurately set up to give SCALE speed .

**■ FIGURE 1. Placement of the four photocell track sensors. The speedometer distance should be exactly the same on either side of the crossing and accurately measured for inclusion in the software.**



The Calibration process to get from the room light level to a "threshold" digital number

**■ FIGURE 2. The relationship between the light level and resistance of a photosensor. By using them in a simple voltage divider and measuring their output levels, a "threshold" number is established for the software.**

normal light to fully covered in the layout room environment. I call it the "threshold" number. It will depend on the ambient room light at the final installation, but we can simulate layout lighting conditions and do a calibration job to determine the number we need.

**Figure 2** shows the concept and simple hardware to move from light levels and the resistance of the LDR to a sensor threshold number. Of all the LDRs I have used over the years, I don't think I have ever found two batches with the same bright to dark resistances. A simple voltage divider will provide the final interface for each of the sensors to the processor.

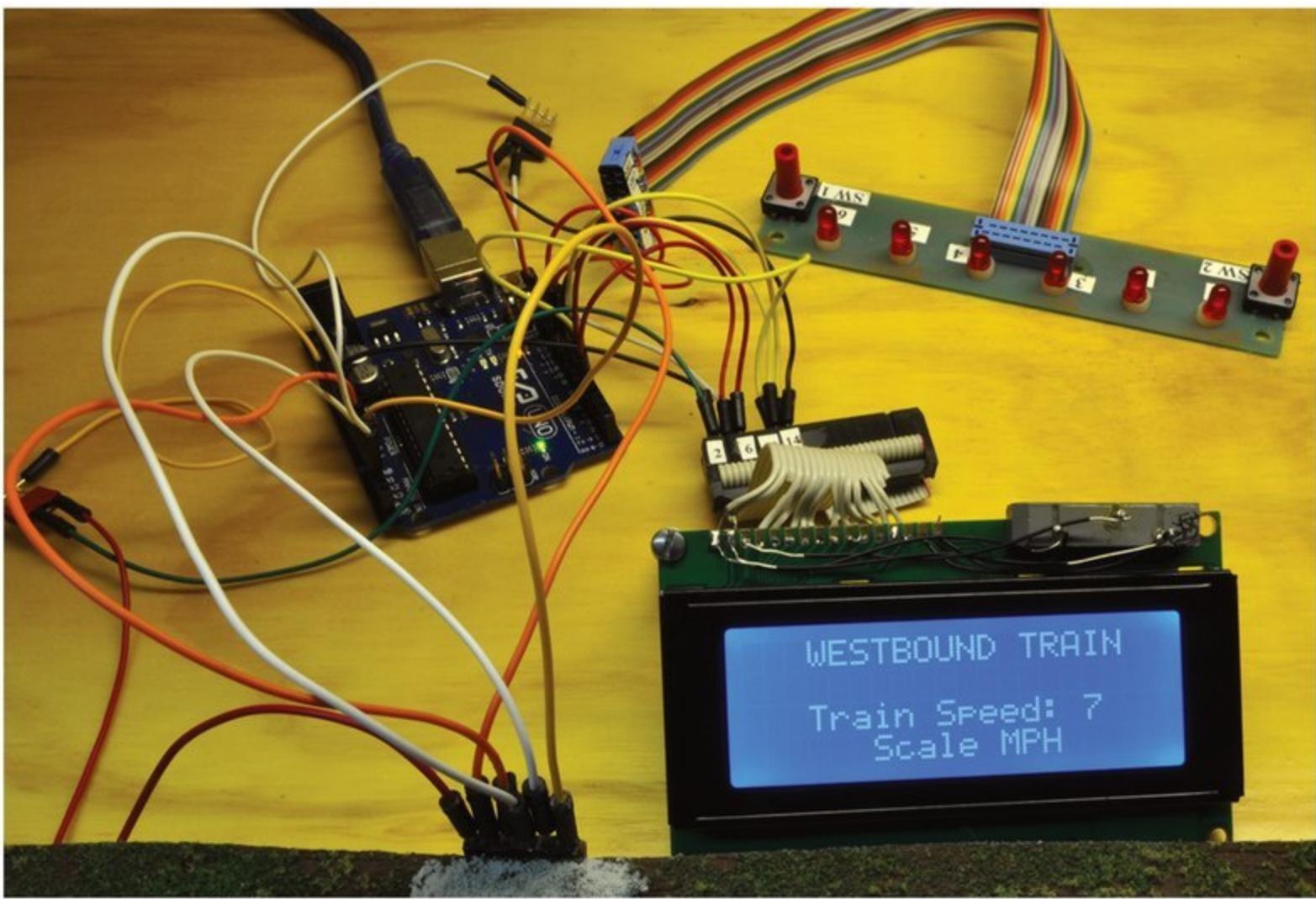
**Photo 1** shows the mock-up on the bench for the four sensors I used. You can build a much simpler single LDR setup for the batch you are using to do your calibration.

Use the overall hookup guide (**Figure 3**) shown in the main

### SOURCE

[www.allelectronics.com](http://www.allelectronics.com)  
[www.allelectronics.com](http://www.allelectronics.com)  
[www.sparkfun.com](http://www.sparkfun.com)  
[www.sparkfun.com](http://www.sparkfun.com)

### PARTS LIST



**PHOTO 1.** The development mockup used to calibrate sensors and the LCD screen display. The screen display shows the *Block Clear* status.

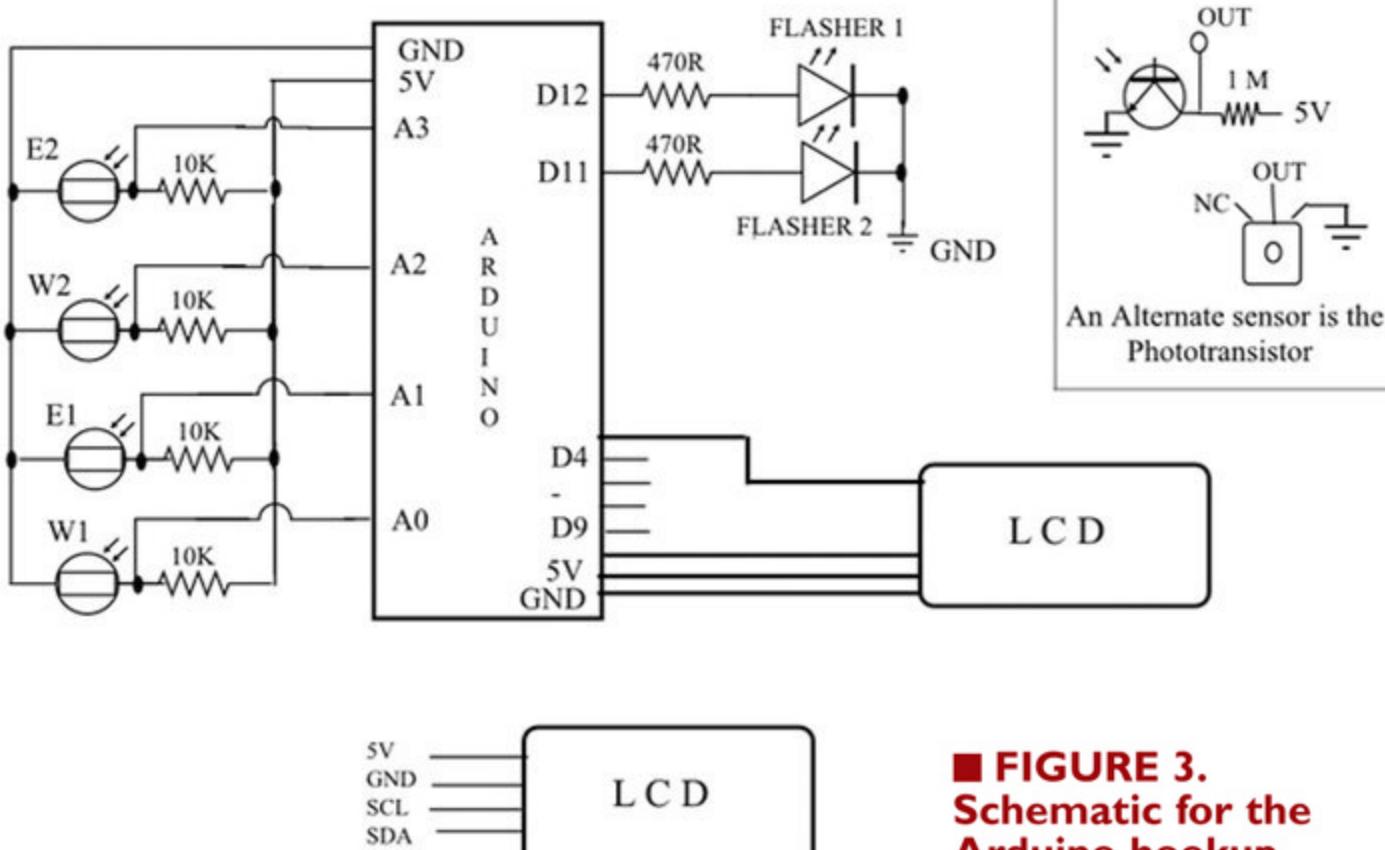
schematic, then run Sketch 1 (available at the article link). It will work for one or all four sensors in the final arrangement. It will allow you to vary and simulate the ambient light level of your layout room. Then, you can observe – on the serial monitor – the change in digital values as you shade the sensors fully. Armed with these values, you can set the threshold number about halfway in between. If your sensors “clear” from partial light between the cars, move your threshold number lower.

let's keep it simple. You could also do the flasher alternations with a hardware setup such as an LM555 chip but – there again – software is sure a lot simpler.

## Two Applications in One ... How It Works

Take a look at **Figure 4**. Here's the sequence the processor will go through as it executes its continuous “loop.” It monitors the westbound sensor and if it changes, a train has entered the area. If not, it checks the eastbound sensor and then returns to the start of the “polling” loop if nothing is found. If sensor W1 has been covered, a train is detected, so it turns on the two LED flashers with a subroutine to time them to alternate at about one cycle per second. It waits for the sensor across the crossing (W2) to be covered, and does nothing until the train has completely come across it. The *while do* loop is great for such stalling.

When the back of the train clears the sensor (W2), it turns off the flashers and starts timing for the speedometer run. The intrinsic Millis function gives us the number of milliseconds as a number since the last

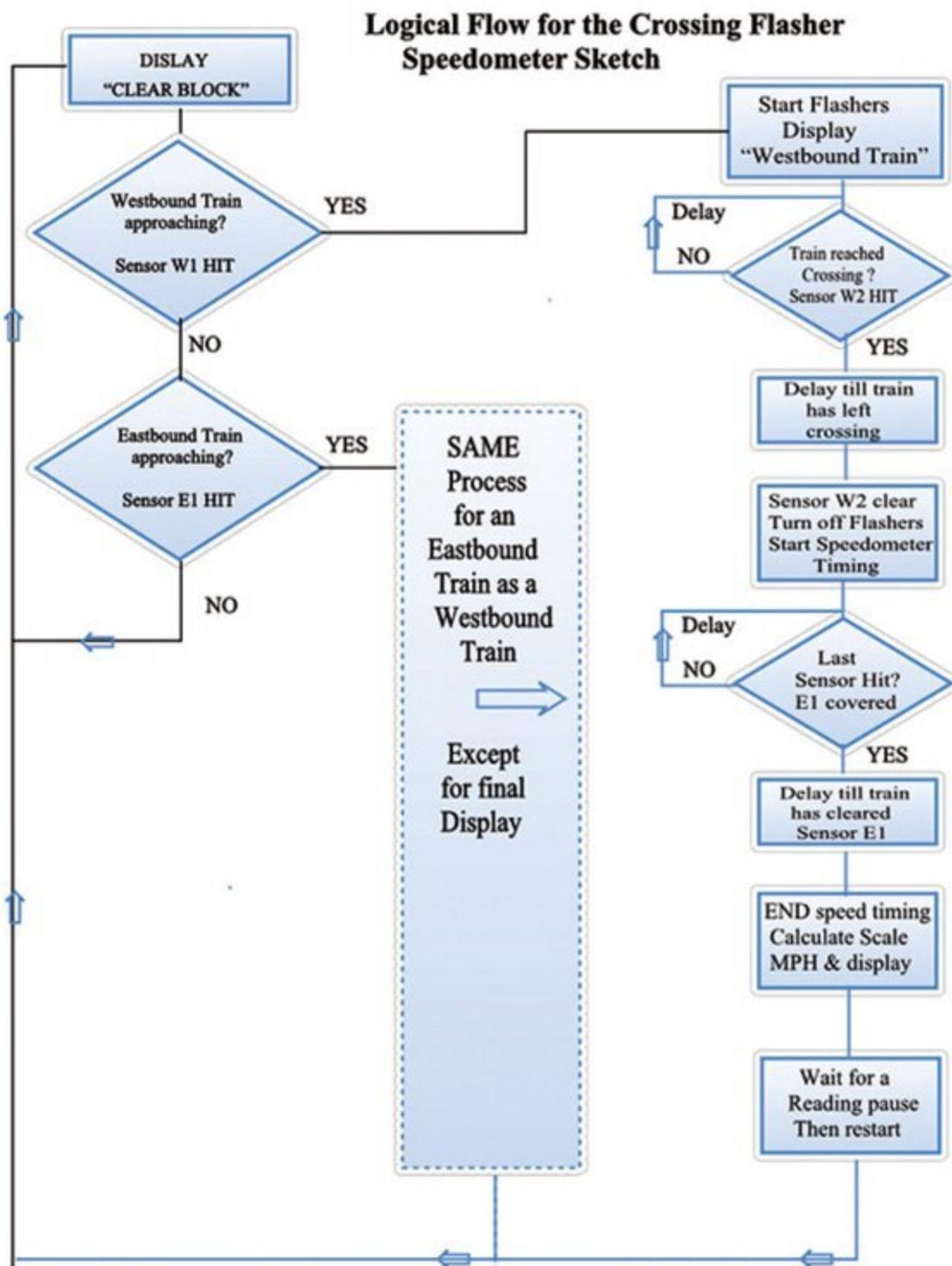


**FIGURE 3.** Schematic for the Arduino hookup.

## What We Need from the Arduino

I used an Arduino Uno. It has six ADC pins, and we will use four of them. We need to alternate – on and off – two flasher LEDs at a rate of about 1 Hz. So, we need two digital pins for that job. The LCD display uses six output pins unless you use one with an I<sup>2</sup>C backpack. Then, you're down to using only the SCI and SDA pins plus five volts and GND.

The current demand for the whole job is under the limit, and we could probably even tie in another job. You could use a hardware interrupt to sense the change in light levels, but the Millis timer won't function during an interrupt service routine, so



**FIGURE 4.** Overall program logic for the flasher/speedometer.

reset, so we can use a start and finish value later to get very accurate real time. When the back of the train finally clears the outer most sensor (E1), it records a “finish” time and computes the speed.

Speed is dependent on your scale, and by changing the scale factor (87 for HO scale, 48 for O, etc.), this scheme will work for any model railroad big or small. The computation of scale speed takes the milliseconds of elapsed time, the distance traveled in inches, and the scale of the model, and turns it into a scale MPH. The same sequence occurs for a train going eastbound with only a difference in the displayed train direction.

The LCD uses the built-in library of the Arduino to produce the display shown for a westbound train. After a delay, the display goes back to a clear block.

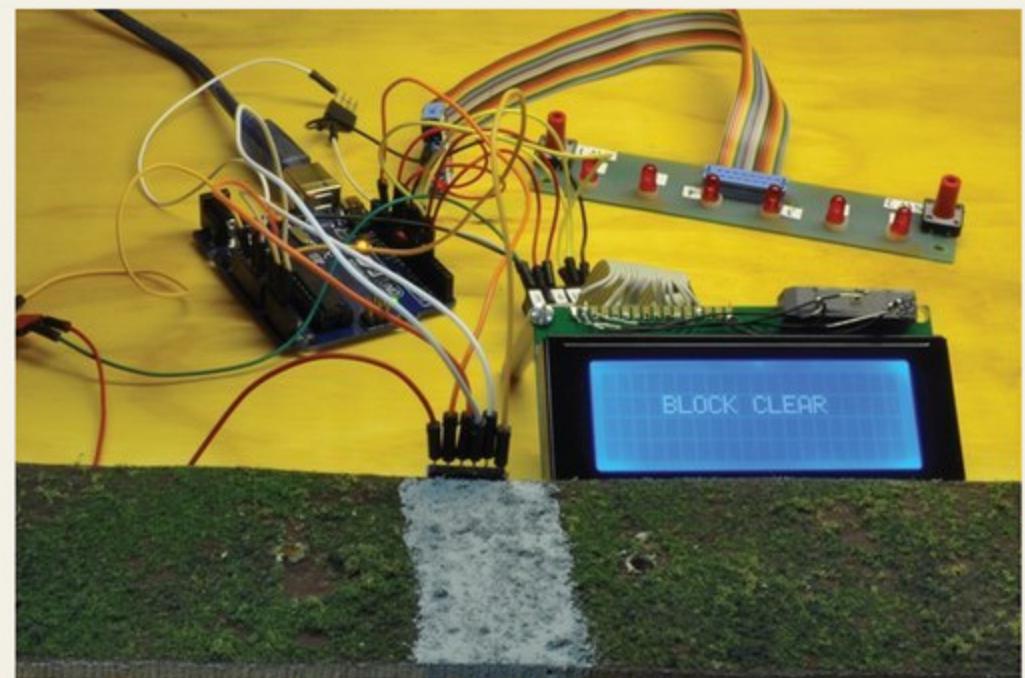
## Making All Model Railroad Animation More Realistic

If you enjoy realistic animation as one more facet of

## Microprocessors and Model Trains Meet Head On!

In order to bring the hardware and software together, a mockup was needed on the bench. Track sensors (LDRs) were mounted in a strip of plywood. A piece of prepainted track roadbed from another project was on hand and worked out just fine. The LCD — which would eventually be mounted in the track framework fascia near the flashers — was also tied to the Arduino Uno with plug ended jumpers.

After software debugging and speedometer time checks, the entire unit is ready for mounting and permanent wiring. It works for any scale model railroad and fits in a very small amount of space.



**PHOTO A.** Screen display after a train has passed.



**PHOTO B.** The flasher on the model railroad. The LCD screen fits into the fascia nearby.

model trains, you can give it a big lift by using a microprocessor and servos. In the larger scales, the commercial crossing gates and moving accessories are usually driven by a solenoid. It's way too “jerky” to be realistic, and begs for the installation of a servo to slow it down. It would be fairly simple to rebuild the device with a servo attached, then slow down the motion and change the timing to come on and off like we did with the flashers in this project. Look around your layout. There are

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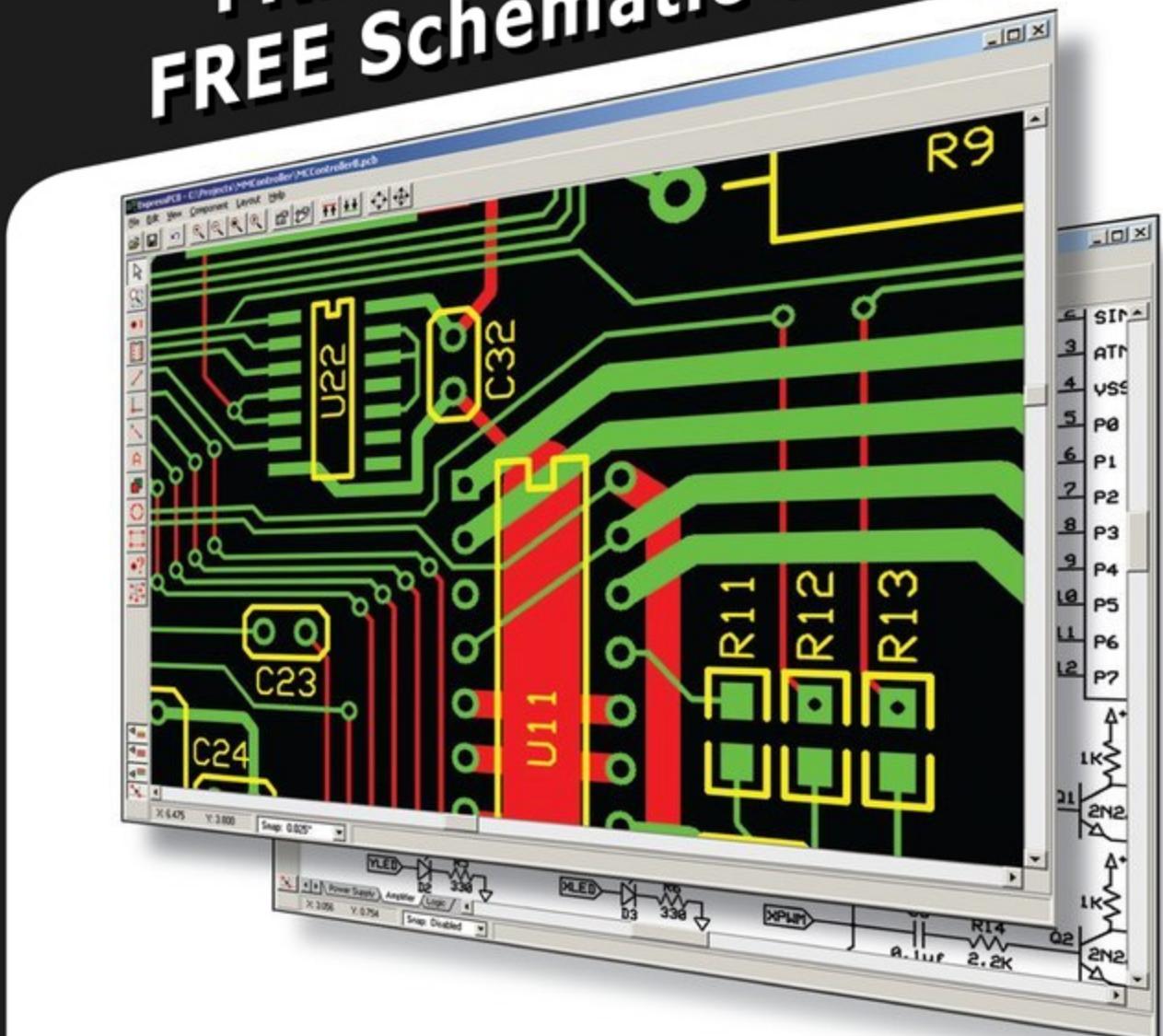
numerous microprocessor projects waiting to be explored!

## Putting It All Together

Check out the **Parts List** for just some of the many places you can find the materials to make this work. There are many sources of open source software for these neat Arduinos, so you will probably find people light years ahead of my approach to this application (but it works for me).

I always keep in mind that model trains and microcontrollers are for fun. That's been true for me for over 50 years! **NV**

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# READER FEEDBACK

Continued from page 7

I am thrilled to see that there were four very informative and very well written articles on radio.

For J.W. Koebel's article, "Fix Up That Old Radio," I saw the mention of the fact that pre-WW II radios had DC power provided by the radio to the speaker to energize the electromagnet in the speaker.

A bit of a warning here. About 20 years ago from the "School of Hard Shocks," I learned these radios have a lot of dangerous voltage on the speaker field wire (90 to 250 volts).

I found out the hard way while checking out the innards (a lot larger and more component-laden than the DeWald 618) of a cabinet radio for a coworker who was finishing the cabinet.

I didn't measure the voltage with a regular meter, but my "skin meter"

said REALLY HIGH and biting.

## Tim Brown N&V Q&A

Good point, Tim. I had one of these old speakers and know exactly what you mean. Also, a good way to learn  $XL = 2\pi fL$  is if you disconnect the speaker while energized (my skin meter registered that, as well)

Bryan Bergeron

## Radio and Rockets

I found Bryan Bergeron's editorial on amateur radio interesting. I agree with him on the points he made.

I would like to take the time to call attention to an increasing use of amateur radio: model rocketry.

It has been done in the past, but I'd like to call specific attention to the efforts of Bdale Garbee and Keith Packard in producing Arduino-based

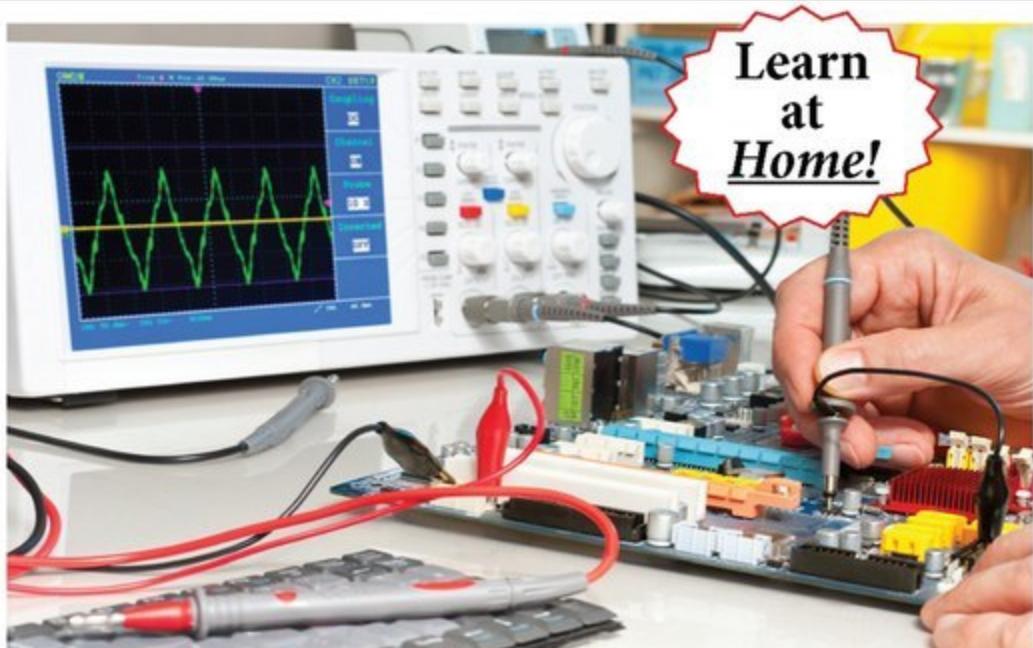
open source flight computers for model rockets. I have no financial connection to the Altus Metrum company but have had the privilege of attending launches where Altus Metrum products were in use, and sometimes Bdale and Keith were there developing stuff.

GPS coordinates of the rocket's location and throughout the flight are relayed to ground via telemetry using one of the ham bands. This link – [altusmetrum.org](http://altusmetrum.org) – should take you to more information that could/should be part of a future application/article of amateur radio.

The flight computer is powerful enough to have a role in balloon-sats and cube-sats.

I hope to see a future article on amateur radio applications in rocketry.

George Shaifer



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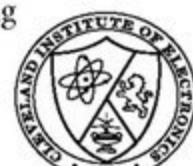
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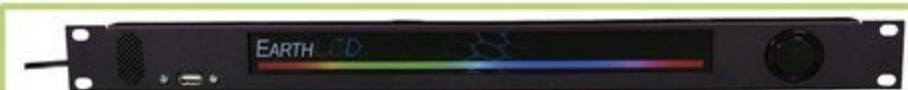


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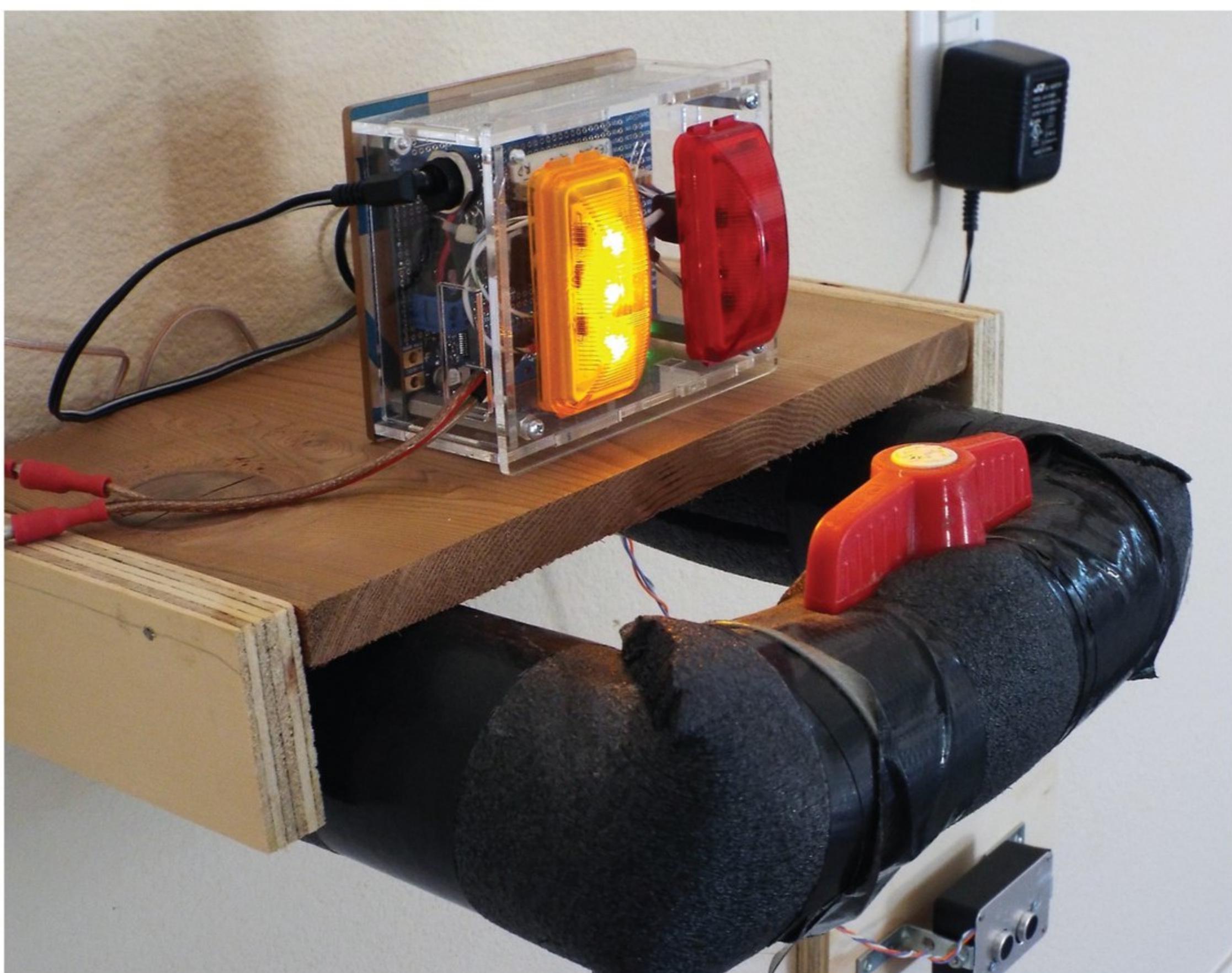
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# THE GARAGE SENTINEL

## A Car Parking Assistant

By Larry Coyle

Post comments on this article and find any associated files and/or downloads at [www.nutsvolts.com/index.php?/magazine/article/august2015\\_Coyle](http://www.nutsvolts.com/index.php?/magazine/article/august2015_Coyle).



It's great to replace your old beat-up car with a brand new one, but when you first bring it home and find that it's a tighter fit in your garage than the old one, you may have a problem. In my case, the new car was a bit longer, and it was a challenge to get it into that sweet spot where it was in far enough to close the garage door, but not so far that I bumped into the storage shelves on the back wall.



I know, I know ... a tennis ball suspended from the ceiling at just the right spot is the classic solution, but with more than one person using the garage — possibly driving different cars or just backing in — that just wouldn't cut it. Also, it would be in the way for somebody walking through the empty garage.

Some of the commercial garage parking aids that I reviewed also had their drawbacks: One system used a laser beam shining down onto the dashboard of the car; others had only a limited range of adjustment or warning lights that were too dim. The situation seemed ripe for a custom electronic solution.

## The System's Approach

I'm always attracted to projects that involve firmware as well as hardware development, and it seemed that a microcontroller — plus some way to sense the location of a car — would be a good start. As feedback to the driver of the car, I envisioned a series of bright lamps mounted on the rear garage wall which would come on as the car passed through three "zones:" 1) when the car was nearly inside the garage; 2) when it was in the prime parking area — which I think of as the "comfort zone;" and 3) when it had gone too far and was close to hitting the wall.

This job is simple enough that almost any microcontroller would do. I have used the Propeller multi-core processor by Parallax ([www.parallax.com](http://www.parallax.com)) for a few projects, and a survey of my supply cabinets turned up an unused Propeller USB project board. This board features — in addition to the Propeller microcontroller unit (MCU) — voltage regulators, clock crystal, USB interface, and a good-sized area for additional components. It would be ideal for this application.

I began to kick around ideas to sense the distance to a car. I considered a motion detector or a diode laser beam reflected off the front of the oncoming vehicle. Neither approach seemed accurate enough, and the laser spot idea wouldn't work if you backed the car in. I could also anticipate setup problems with these schemes.

Eventually, I settled on a non-contact approach using an ultrasonic range finder to measure distance. Parallax sells these devices, good for distances up to three meters (about 10 feet), so I sent for one.

Next, my thoughts turned to the signal lamps. These had to be bright enough to be easily seen in broad daylight. I stewed about this for a time, considering and rejecting several ideas; for instance, using relays to control incandescent bulbs. I found my answer in a local automobile parts store. For just a few dollars each, I was able to pick up some running lights — also known as clearance lights — of the type used on big truck trailers. These lamps contain several high-intensity LEDs; are very

visible — even in bright sunshine; and run nicely on 9–16 volts DC. The lamps come in two colors (red and amber), so I bought one of each and decided I would use firmware to show when the driver had strayed into the third zone (mentioned above) and needed to back up.

## Refining the Idea

I didn't want the system to run 24 hours a day — mainly as a power conservation measure — but also to turn off the ultrasonic pinger when it wasn't needed, since bats, moths, and (I suppose) other creatures are sensitive to these frequencies. So, I looked for some way to apply power to the system when the garage door opened, leave it on for a few minutes while the car was being parked, and then automatically shut down.

A micro switch activated by the garage door opener was the most direct approach. However, there were some mechanical difficulties involved in my case, so I began looking for another plan. Like most overhead garage door systems, mine features an overhead lamp which turns on when the door opens and remains on for about five minutes. Just what I wanted!

To avoid any modification or direct connection to the existing door opener (and possible grounding and safety problems), I decided to go with an inexpensive cadmium sulphide (CdS) light-sensitive resistor which I would locate inside the overhead light fixture, close to the bulb. The change in resistance when the overhead light came on would turn on a MOSFET which would apply power to the MCU board and the signal lights.

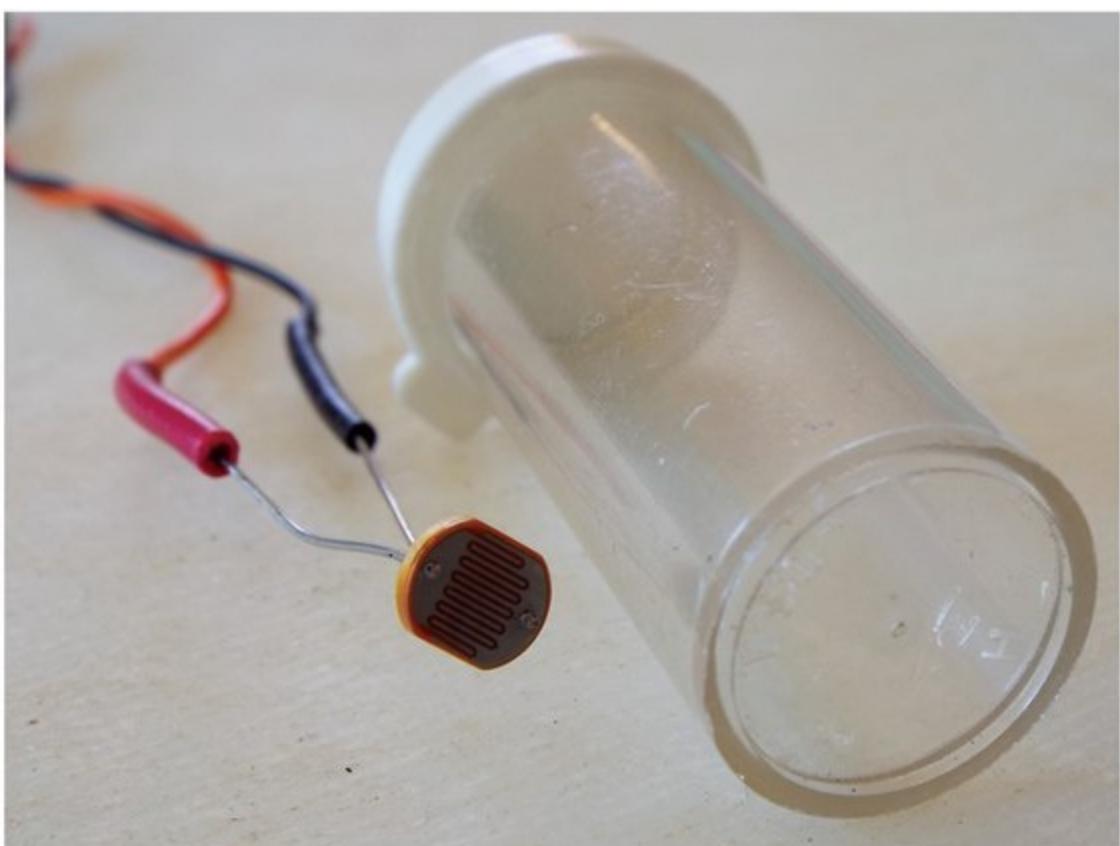
Now, I felt I had the basic system design pinned down. With the huge capability inherent in the Propeller and the ease of programming it, any reasonable refinements could come later.

## A Few Preliminary Tests

My first priority was to see if the components I had in mind were adequate for the job.

First, I checked the current requirements for the LED lamps and found them to be fairly modest — only about 40 millamps at 12 VDC for each lamp. Adding in 30 millamps for the ultrasonic range sensor and 20 mA for the Propeller microcontroller board meant that the whole thing could easily be powered from a small wall wart power supply.

Next, I soldered about 30 feet of twisted pair to the terminals of the CdS photoresistor and mounted it inside a clear plastic bottle. Refer to **Figure 1**. I fastened it with tape inside the garage door opener overhead lamp close to the bulb, and hooked up my digital multimeter to measure the resistance. I was pleased to see that with the



**■ FIGURE 1. Cadmium sulfide photoresistor and plastic bottle ready to receive it.**

overhead light off, the meter read over one megohm; when the light was lit, the resistance dropped to less than 20K ohms. Plenty of range for switching a MOSFET!

I had no qualms about the Propeller MCU chip. From other projects, I knew it had more than enough capability for this job, since only four I/O pins are needed: two for the LEDs; one for the ultrasonic sensor; and one for a pushbutton switch used for calibrating distance (more on that later). Processor speed is not an issue either for this task.

## The Circuit Design

At this point, I felt I had enough of a handle on things to go ahead with the actual circuit design. The system block diagram in **Figure 2** shows how the major components work together. The system block labeled "Power Control" contains a P-channel MOSFET whose function is to switch power to the rest of the circuit under

control of the optical sensor. In other words, it acts as a solid-state relay.

Circuit details are shown in the schematic in **Figure 3**. The NPN transistor, Q1, is driven to cut off when the sensor is dark; i.e., when its resistance is high. This allows the gate of the MOSFET, Q2, to be pulled high, turning off Q2 and thus cutting off power to the rest of the circuit. The only current drain now is a few microamps due to leakage through the MOSFET and the photoresistor. Diode, D2, in the emitter of Q1 is there just to ensure that Q1 cuts off completely – even if there may be a slight leakage of light onto the sensor – as on a bright sunny day with light streaming through the garage window.

Note that an NPN Darlington transistor – a BC517, for example – could be used in place of the Q1/D2 combination since the Darlington inherently has a higher base-to-emitter forward voltage drop ( $V_{be}$ ) than the 2N4401. I just used what I had available.

The LEDs get their power directly from the raw DC input. As mentioned previously, each LED lamp uses about 40 mA when it's on and is controlled by a 2N4401 switching transistor. There is nothing critical about these transistors, and almost any NPN capable of handling a collector-to-emitter voltage ( $V_{ce}$ ) greater than the input supply voltage will do.

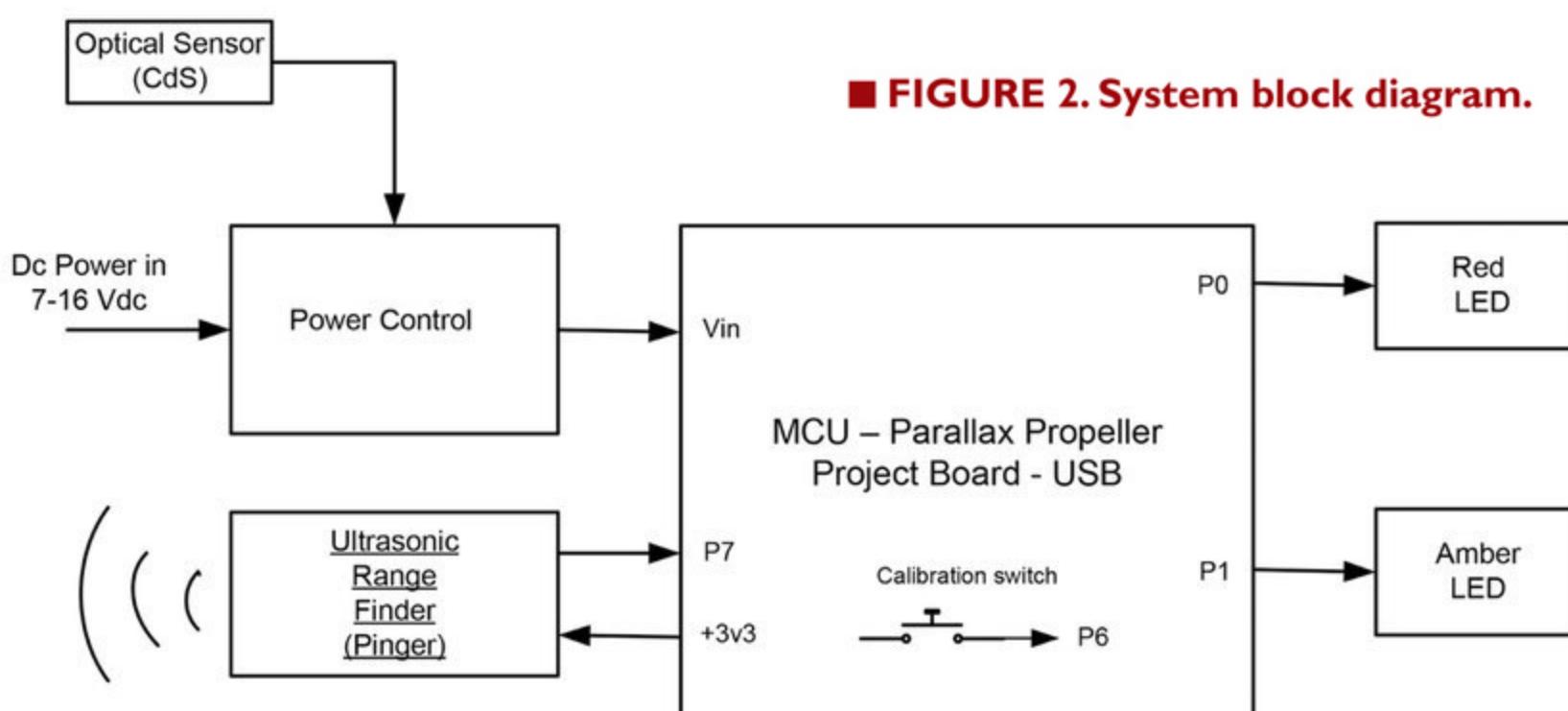
Momentary normally open (NO) pushbutton switch, S1, simply provides a user input signal for use during the calibration procedure. This is explained in the Calibration section of this article. Schottky diode, D1, is in the circuit to prevent any disastrous consequences if the power source is accidentally reversed.

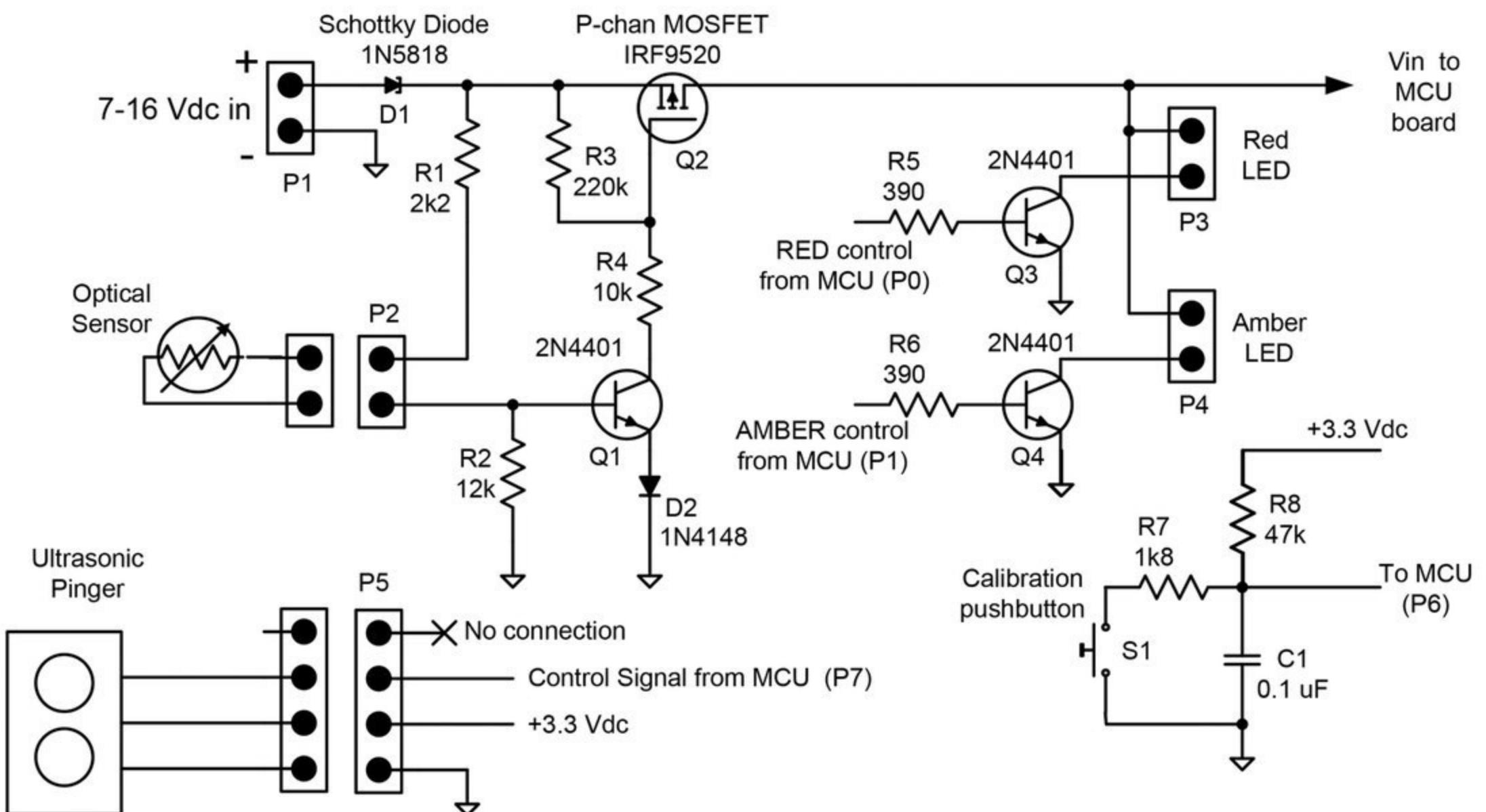
## The Pinger

The ultrasonic pinger is an easy-to-use non-contacting distance sensor which operates on the same principle as range-finding radar. Besides power and ground, it uses just a single control pin driven by the microcontroller.

When the control pin receives a pulse from the MCU, the pinger emits a burst of high-frequency (40 kHz) sound. The control pin then outputs a high level until an echo return is received.

The width of the signal from the control pin is the same as the echo time delay, and is therefore a measure of the distance to the reflecting object. Parallax specifies a supply voltage of five volts for the pinger, but I found that the





**FIGURE 3. Electrical schematic.** All components shown here (except for the pinger and optical sensor) are through-hole devices and are mounted in the prototyping area of the Propeller USB project board.

device works with no problems at 3.3 volts. I was prepared to install a level-shifting circuit between the pinger control pin and the MCU using a single-transistor circuit (which has appeared several times in the pages of *Nuts & Volts*), but it seemed to be unnecessary in this case.

I have included a description of a suitable level-shifter with the information package at the article link if you should choose to go that way.

## Firmware

The firmware for the garage sentinel project was written entirely in the Propeller Spin language, and is very basic and easy to understand. The program begins by initializing the I/O pins and retrieving the near and far limits of the comfort zone (program variables *nearmark* and *farmark*), which have been stored in EEPROM during the calibration process.

Next, it enters an endless loop which repeats every 250 milliseconds, where the first order of business is to check the state of the calibration pushbutton.

If the button is depressed (logic low), a calibration routine (called "method" in the Spin language) is entered. If not, the program sets the MCU pinger control pin as an output and pulses it high for 50 microseconds.

Next, it sets the pin as an input and monitors the duration of the return signal. The duration is converted

from system clock counts to distance in centimeters and is stored in the program variable *distance*.

A series of comparisons follow:

- If *distance* is greater than 260 cm, both LEDs are turned off.
- If *distance* is less than 260 cm, the car is approaching the comfort zone and the amber LED is turned on.
- If *distance* is less than the maximum zone boundary (*farmark*), the car is within the comfort zone and the red LED only is turned on.
- If *distance* is less than the minimum zone boundary (*nearmark*), it's beyond the comfort zone and the red LED flashes at a rate of twice per second.

The loop then repeats from the beginning.

## Calibration

In this mode, the user gets to set the distances marking the near and far limits of the comfort zone for parking the vehicle. These distances are stored in program variables *nearmark* and *farmark*, respectively, and also in EEPROM so they can be retrieved every time power is applied to the system. As mentioned in the firmware description, the firmware periodically checks the state of

the calibration pushbutton. If the button is pressed, the calibration method is entered. Here, the duration of the button press is captured, and again a series of comparisons is carried out:

- If the button press is less than one second or more than 20 seconds, the calibration method is exited and control returns to the main program.
- If the button press is between one and five seconds, the distance reading is stored in *nearmark* and in EEPROM, and the calibration routine is exited.
- If the button press is between five and 20 seconds, the distance is stored in *farmark* and in EEPROM, and the routine is exited.

In practice, the actual calibration procedure is pretty straightforward:

**First step:** Drive your car slowly into the garage and stop where you consider the beginning of the comfort zone to be. Then, press the calibration pushbutton for more than five but less than 20 seconds. This saves the location in EEPROM and in the *farmark* program variable.

**Second step:** Pull the car forward to where you want the end of the comfort zone to be. Now, press the calibration pushbutton for at least one second, but not more than five seconds. This records the *nearmark* location.

That's all there is to it!

## Hardware

For an enclosure, I went with the neat clear plastic multiboard project box offered by Parallax that is designed

to fit the Propeller USB project board. There is plenty of room on the board to accommodate the small number of components required. **Figure 4** is a picture of the board populated with all components.

I needed to bring two external cables into the box from the remotely-located optical sensor and the three-wire cable to the pinger. There are several knockout sections of various sizes convenient for feeding cables into the box. I had to cut a hole in a side panel to mount a DC power coax jack, and another hole to give me access to the USB port on the project board (in case I wanted to modify the firmware after assembling everything).

I mounted the two LED lamps on the front panel of the enclosure where they fit very nicely, as shown in **Figure 5**. The final configuration of the complete garage sentinel system as set up in my garage is shown on the first page of the article

In that photo, you can also see that I put the pinger in a small separate box at the end of a short cable since I had to put it low enough to "see" the front of the car. Of course, the box with the LED lamps had to be high enough for the driver to see it.

To power this project, I used a wall wart type of external power supply, capable of supplying about 200 mA at nine volts DC. One word of caution which applies to any home-built project using this type of power supply: **Be sure to check the open circuit voltage (i.e., the unloaded output voltage) at least once before connecting your wall wart to the device you are building.**

Some of these supplies can put out nearly twice their rated voltage without a load, and if you turn on the supply before connecting it to your project, the brief over-voltage before it settles down could be extremely bad news to your system.

ITEM	DESCRIPTION	VALUE	MODEL
R1	1/4 watt resistor	2.2K ohms	
R2	1/4 watt resistor	12K ohms	
R3	1/4 watt resistor	220K ohms	
R4	1/4 watt resistor	10K ohms	
R5, R6	1/4 watt resistor	390 ohms	
R7	1/4 watt resistor	1.8K ohms	
R8	1/4 watt resistor	47K ohms	
D1	Schottky diode		1N5818
D2	Silicon diode		1N4148
Q1, Q3, Q4	NPN transistor		2N4401
Q2	P-channel MOSFET		IRF9520
S1	NO pushbutton switch		
P1, P2, P3, P4	Male pin header	2 pins	
P5	Male pin header	4 pins	
	Red high-intensity LED		
	Amber high-intensity LED		
	Propeller USB project board		Parallax P/N 32810
	Ultrasonic range sensor		Parallax P/N 28015
	Cadmium sulfide photoresistive optical sensor		Parallax P/N 350-00009
	Multiboard enclosure, clear plastic		Parallax P/N 721-32212
	Power supply (wall wart)	9-16 VDC 100 mA or greater	

## PARTS LIST

## Temperature Dependence

The ultrasonic pinger used in this project can be utilized to measure distance to nearly any surface – solid or liquid. If perhaps you are thinking of other applications, I should mention here that the performance of the sensor is a bit dependent on air temperature. This doesn't imply a defect in the pinger's design; it's just a property of sound in air.

Sound travels faster in warm air than in cold, and since we're using the time delay of the return echo to determine the range, temperature can affect the distance reading. The folks at Parallax provide a handy formula on the pinger datasheet for correcting the range measurements. If you are after the ultimate accuracy, you will need to do this compensation.

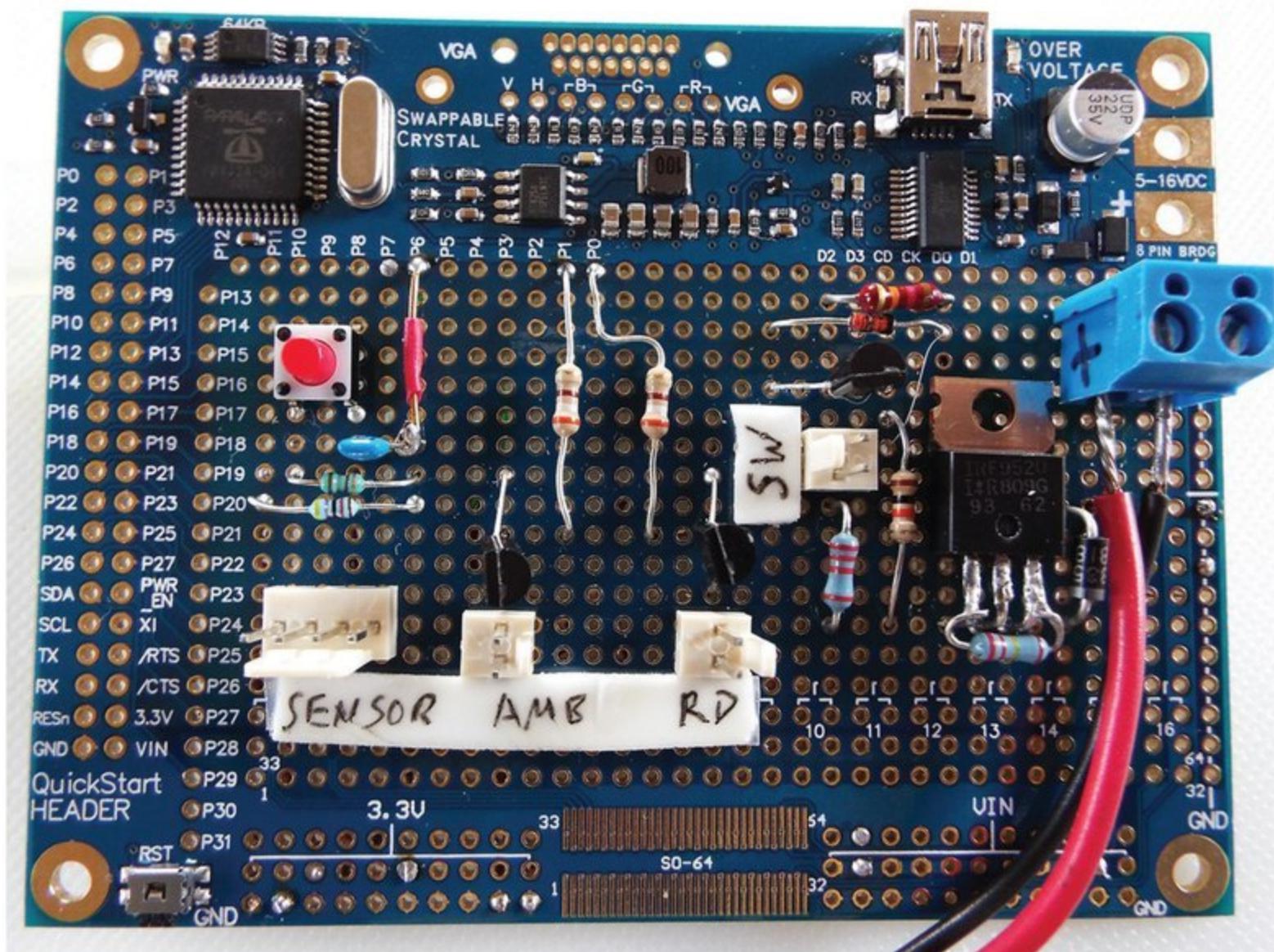
This means adding a temperature sensor to the system and a bit of firmware to do the arithmetic. Not difficult to do, if you need the accuracy; I chose to ignore this problem for the garage sentinel since my garage stays pretty much between 3 and 50 degrees C, resulting in a possible error of about plus or minus four percent. This amounts to just a few centimeters at the closest approach. Not enough to worry about for parking the car.

## Future Upgrades

As mentioned, there is plenty of untapped capability in the Propeller MCU on this project. I can imagine adding a beeper or other audible alarm when the car gets too close to the garage wall as an additional warning besides the flashing LED. Or, another cool feature might be to continuously increase the LED flash rate as the car gets farther past the comfort zone.

Also, it shouldn't take much to add a second pinger, arranged to give a wider coverage angle. This would be useful if you have a wide garage, or more than one car.

I may build up a future version of this device using some of these upgrade ideas, but for the present it suits my needs as-is. Now, I can always



■ FIGURE 4. The Propeller USB project board with all components mounted. The calibration pushbutton is the red button in the left center of the board. The cable from the optical sensor plugs into the two-pin header labeled "SW."

ease the car into the parking comfort zone without hitting anything, and with enough room to walk around the car in front and back after the garage door is closed. **NV**



■ FIGURE 5. The LED lamps mounted on the front panel of the enclosure.

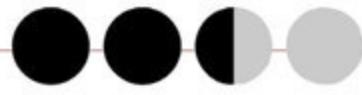
# A WEB CONTROLLED MUSIC AND INTERNET RADIO PLAYER

By Craig A. Lindley



Post comments on this article and find any associated files and/or downloads at [www.nutsvolts.com/index.php?/magazine/article/august2015\\_Lindley](http://www.nutsvolts.com/index.php?/magazine/article/august2015_Lindley).

Long-time readers of *Nuts & Volts* may recall that I have covered Internet radio topics a couple of times in the past. My first build was based on a repurposed Wi-Fi router and was described in the article, "Build Your Own Wi-Fi Internet Radio" in the March 2012 issue. With the arrival of the Raspberry Pi (RPi), I updated (and simplified) my approach and documented that in the article, "More Raspberry Pi Anyone?" in the August 2013 issue. These systems have served me well over the past few years, but when I stumbled across the Pi MusicBox software for the Raspberry Pi, I knew I had to revisit this again. The Pi MusicBox software combined with a RPi (B+ or Pi 2 B) makes for an incredibly flexible music system. I truly cannot envision a system much more flexible than this.



The Pi MusicBox software running on the RPi provides the following features:

- Remote control using a web interface from any browser on any device or by using an MPD client app like MPDroid for Android.
- A headless audio player for streaming music from Spotify, SoundCloud, Google Music, and Podcasts (with iTunes, gPodder directories), local and networked music files (MP3/OGG/FLAC/AAC), and Web/Internet radio (with TuneIn, Dirble, AudioAddict, Soma FM, and Subsonic).
- Includes AirTunes/AirPlay and DLNA/OpenHome for streaming from a phone, tablet (iOS and Android), or PC using software like BubbleUPnP.
- Flexible USB audio support for all kinds of USB sound modules including generic (like I used here), HifiBerry (DAC/Digi/AMP/+), IQ Audio, etc., for higher end audiophile applications.
- Can play music files from the RPi's SD card, from an attached USB Flash or USB hard drive, and over a local area network (LAN).
- Wi-Fi support for Raspbian (the officially recommended

RPi operating system software) supported Wi-Fi adapters.

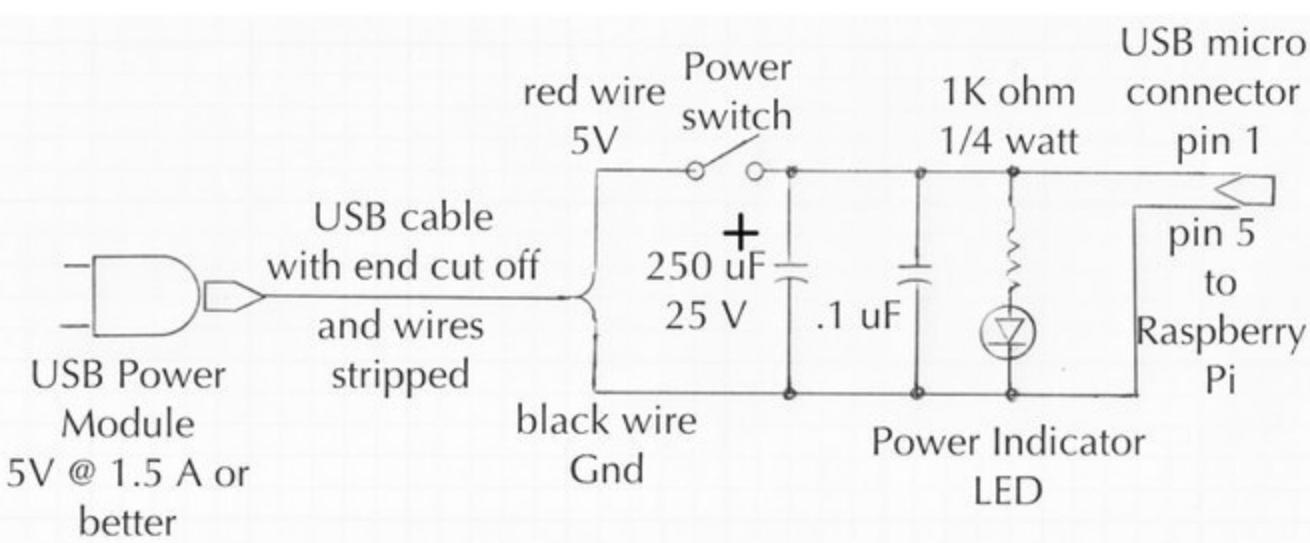
The music player system I'll describe in this article (refer to lead photo) is like having a Wi-Fi remote-controllable iPod that also plays 100s of Internet radio stations, and can play music from many streaming services. I have over 500 digitized CDs online, and this system plays them flawlessly. In fact, I copied my entire iTunes music library onto a 64 GB USB Flash drive that I included in my new MusicBox player system and away I went.

The project itself is relatively simple to build with the packaging being the hardest part. If you look around for deals, you can build this music player system for around \$80. You will need a stereo system to plug into, however, as the build I describe here does not include amplifiers or speakers.

Finally, even though Pi MusicBox software is hosted on the Raspbian version of Linux used on the RPi, there is no requirement for using the Linux command line during installation or normal operation. A Parts List for the music player for the configuration I built is shown in **Figure 1**. The schematic is shown in **Figure 2**.

Part Description	Part Number	Source
Raspberry Pi Model B+ or Raspberry Pi 2 Model B	83-16317 or 83-16530	<a href="http://mcmelectronics.com">mcmelectronics.com</a>
MicroSD Card 2 GB or larger	83-11235	<a href="http://mcmelectronics.com">mcmelectronics.com</a>
USB Audio Adapter	Syba SD-CM-UAUD USB Stereo Audio Adapter	<a href="http://amazon.com">amazon.com</a>
USB Wi-Fi Adapter	Miniature Wi-Fi (802.11b/g/n) Module ID: 814	<a href="http://adafruit.com">adafruit.com</a>
USB 64 GB Flash Drive	PNY Attaché 64 GB USB 2.0 Flash Drive - P-FD64GATT03-GE	<a href="http://amazon.com">amazon.com</a>
Male Micro USB Connector	Micro USB Type A Male five-pin Connector	<a href="http://amazon.com">amazon.com</a>
Power Switch	Any switch you would like to use	
Power Indicator LED	Any color and/or size (I used a color changing RGB LED.)	
1K ohm 1/4 watt Resistor		
USB Cable (minimum three foot length)	83-14274	<a href="http://mcmelectronics.com">mcmelectronics.com</a>
USB Power Adapter 2 amps @ 5 volts	28-19300	<a href="http://mcmelectronics.com">mcmelectronics.com</a>
Audio Cable	Stereo cable for connecting USB audio module to your stereo system	
250 µF @ 25 volts or greater Filter Capacitor		
.1 µF Capacitor		
Wire, solder, baltic birch plywood, smoked plastic sheeting, wood screws, and other misc. hardware		

**FIGURE 1.  
PARTS  
LIST**



**Figure 2.** Music player schematic.

## Software Preparation and Configuration

For this part of the process, you will need a computer system that is capable of writing to a microSD card (2 GB minimum size), and that is connected to the Internet and able to download files.

The first item of business is to download the Pi MusicBox software from [www.woutervanwijk.nl/pimusicbox/musicbox0.6.zip](http://www.woutervanwijk.nl/pimusicbox/musicbox0.6.zip). This is a rather large file, so it will take some time to download. Once downloaded, unzip the file to get the file "musicbox0.6.img" contained within. This is the operating system's image file that must be transferred to the microSD card. How this is done depends on the computer system you are using. For instructions on how to do this on your computer, go to [http://elinux.org/RPi\\_Easy\\_SD\\_Card\\_Setup](http://elinux.org/RPi_Easy_SD_Card_Setup).

The Pi MusicBox software uses a file named *settings.ini* for all of its configuration settings. The file is structured as a Windows *ini* file where all lines starting with a # are comments. Comments within the configuration file describe each configurable item, so read the comments carefully. Some configuration lines are commented out by default, so if you want to use them, remove the # at the beginning of the line.

Once the Pi MusicBox software is operational, you can manipulate the configuration settings online through the web interface. It is also possible to enable SSH in the Pi MusicBox software so the configuration file can be accessed and manipulated remotely by logging into the RPi (default username: root; password: musicbox) and using an editor like Nano or Vi to edit the configuration file. At runtime, the configuration file can be found at */boot/config/settings.ini*.

You can also edit the Pi MusicBox settings file directly on the SD memory card before the card is inserted into the RPi. To do this, put the SD card into your computer and open the contents of the file */config/settings.ini* with your favorite text editor.

Most of the configuration items are set to reasonable

initial values, but some must be tailored to your specific environment. At a minimum, the following two items must be set:

```
wifi_network = your_wifi_
networks_SSID
wifi_password = your_wifi_
networks_password
```

Set the *wifi\_network* value to the SSID of your Wi-Fi network and set the *wifi\_password* entry to the password of your Wi-Fi network.

Since I like to be able to remotely log in to the RPi in the music player, I always enable SSH (Secure Shell) as follows:

```
enable_ssh = true
```

Pi MusicBox must scan local and networked music files before they will be selectable in the web user interface. Scanning can take a long time if there are a lot of music files to process. If your music library is very dynamic, uncomment the *scan\_always* entry which will cause a rescan every time your music device is powered up. If your music library is relatively static, set *scan\_once* to true:

```
scan_once = false
#scan_always = true
```

Then, when the Pi MusicBox software runs, it will scan your music library once and then reset *scan\_once* to false automatically. If you add new music to your library, set *scan\_once* to true again and reboot.

## Hardware Configuration

In my music player, I used a 64 GB USB Flash drive for holding my complete music library. As mentioned, I copied my entire iTunes music directory to this device so I would have local access to all of my digitized music. Before doing this, however, I had to reformat the Flash drive into plain FAT32 format. This was necessary because the Flash drive I used came formatted as exFAT which the Pi MusicBox software does not support natively.

Once I had reformatted the Flash drive, it was an easy – but long – process to copy the music files (33 GB total). Once you are finished with copying, make sure to properly eject the USB Flash drive so as not to corrupt it accidentally when you unplug it from your computer.

## Music Player Packaging

How one packages a device such as this music player

is a matter of personal choice, taste, and budget. When I started thinking about how I would do it, I looked around my shop and found some leftover baltic birch (BB) plywood and some 1/8" black translucent sheet plastic/acrylic that I had from past projects.

So, that is what I decided to use. I will describe what I did in the hope it will be helpful at least for a starting point in whatever you do if you decide to build a music player for yourself. Note if you use a different USB sound module than I did you may have to alter the dimensions given in the discussion that follows.

First thing I did was to figure out the size of the enclosure I needed to build to house all of the components: RPi, Flash drive, USB sound module, etc. So, I plugged all of the components together and with a ruler determined the minimum volume necessary.

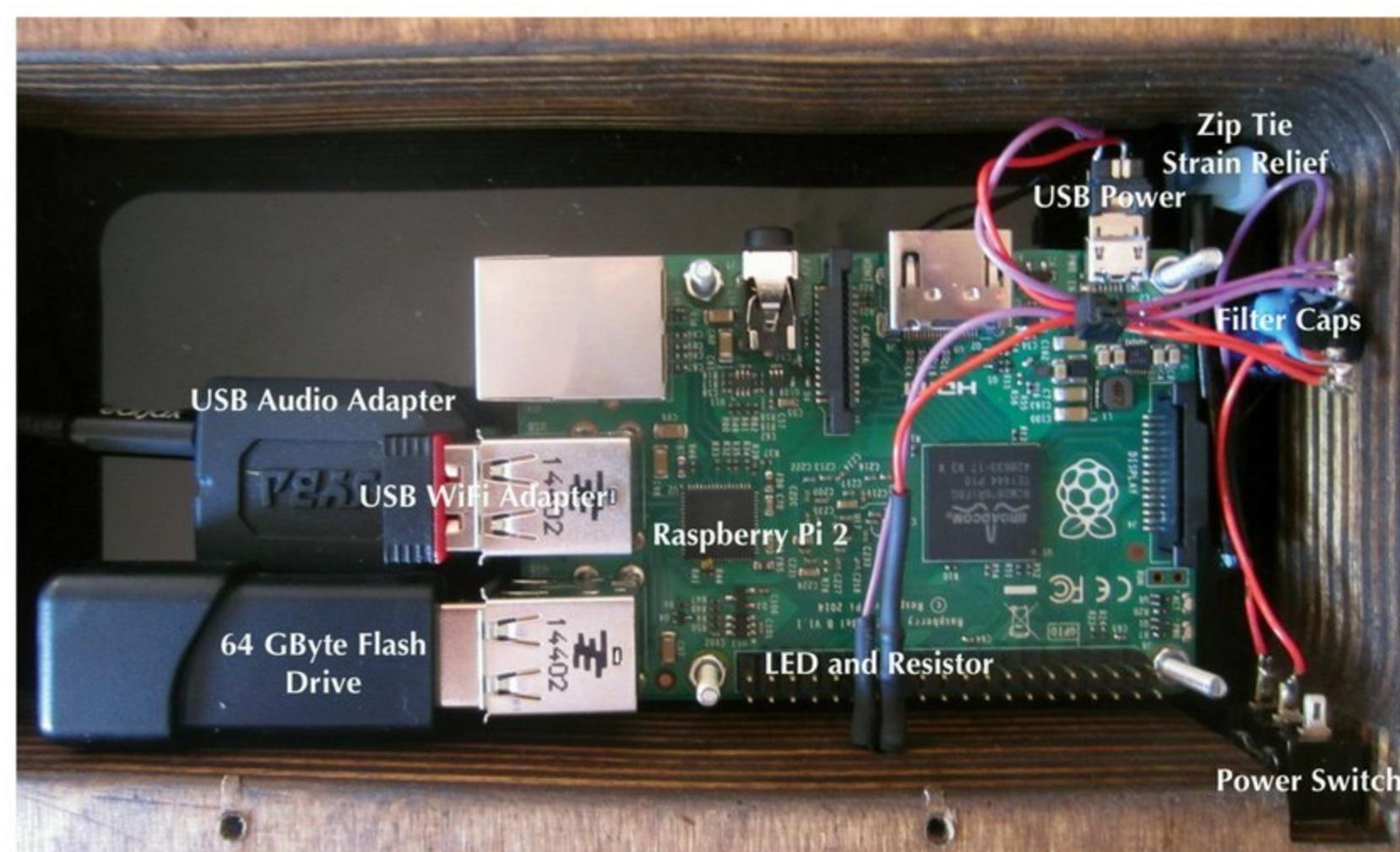
I decided the internal dimensions had to be at least 2-1/2" deep by 6" wide and 1-1/8" tall. Past experience told me it was not a good idea to try and minimize the enclosure size, so I decided on slightly larger internal dimensions of 3" deep by 7" wide and 1-1/4" tall. This size would allow me to easily fit all of the required components.

Next, I decided that the enclosure I was to make from BB would need to have at least a 1/2" thick border to make it structurally rigid. So, the outside dimension of the enclosure would be 8" by 4". To achieve the desired height, I would need to glue 3/4" and 1/2" pieces of the BB plywood together. With that decided, I made a template out of 1/4" MDF that was 8" by 4". I rounded the corners of the template for a more sleek look (IMHO). I marked the template with an arrow to indicate the top front side.

On my router table, I set up a flush cutting bit with a bearing on the bottom that would ride on the template



**Photo 1.** Case/enclosure during construction.

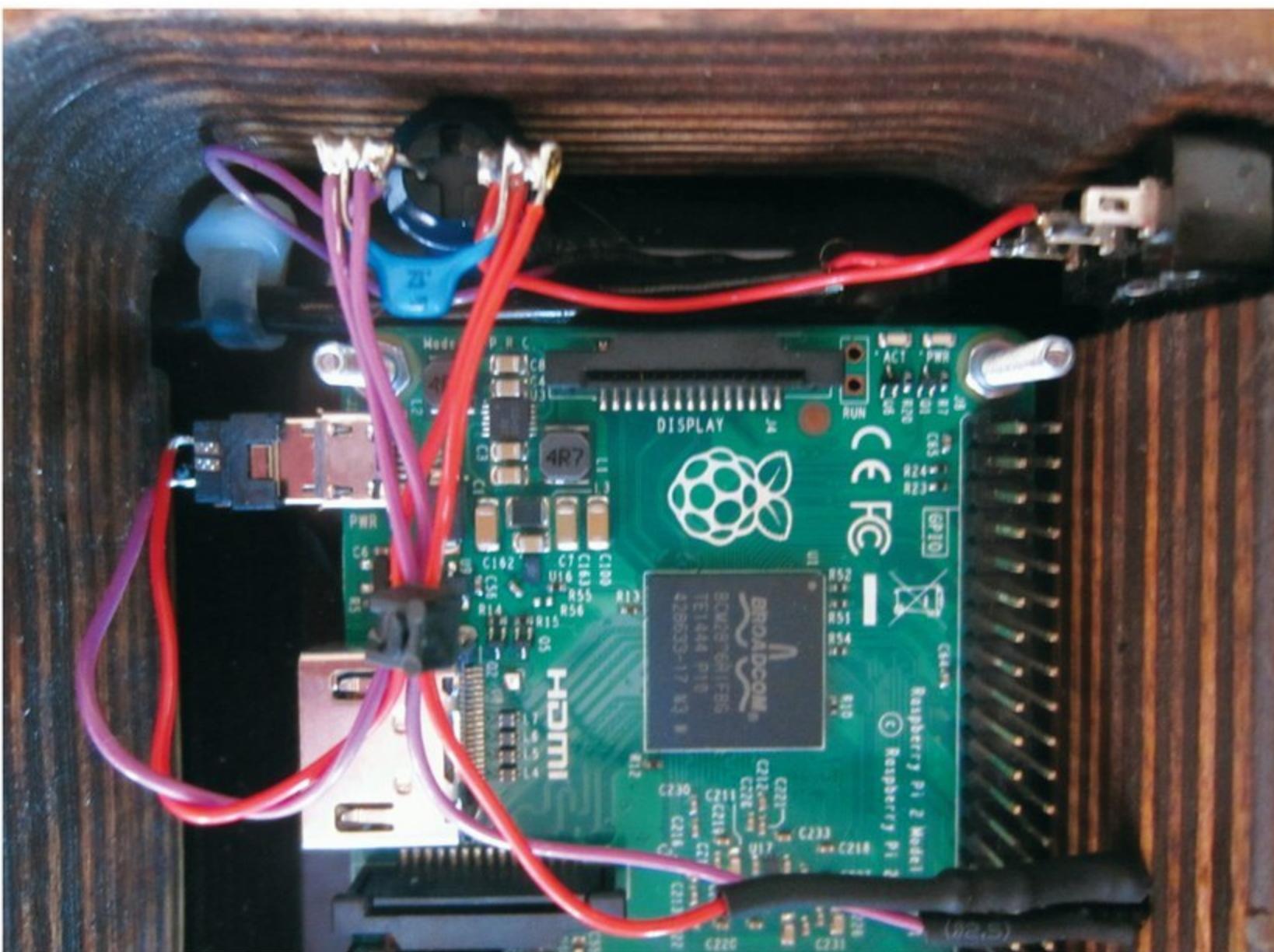


**Photo 2.** Internal view of the music player.

## Resources

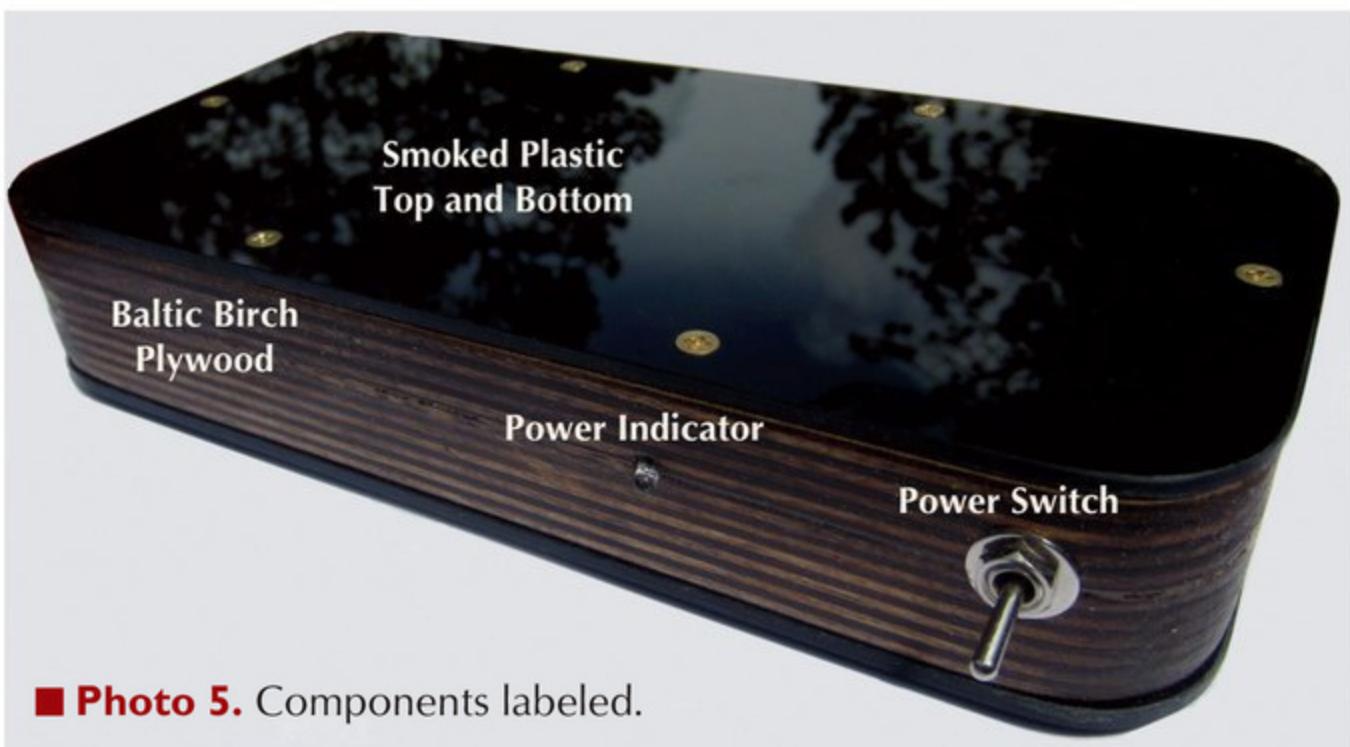
The following websites have information pertinent to this discussion:

- The website of the developer of the Pi MusicBox software is [www.woutervanwijk.nl/pimusicbox/](http://www.woutervanwijk.nl/pimusicbox/).
- A forum for users of the Pi MusicBox software is available at <https://discuss.mopidy.com/c/pi-musicbox>.
- A list of FAQs about the Pi MusicBox is available at [www.woutervanwijk.nl/pimusicbox/faq.html](http://www.woutervanwijk.nl/pimusicbox/faq.html).
- The Pi MusicBox manual is available at [www.woutervanwijk.nl/pimusicbox/MusicBox\\_Manual.pdf](http://www.woutervanwijk.nl/pimusicbox/MusicBox_Manual.pdf).



**■ Photo 3.** Music player wiring closeup; 250  $\mu\text{F}$  capacitor is glued to the plastic bottom and supports all of the wiring.

**■ Photo 4.** Rear view.



**■ Photo 5.** Components labeled.

and allow me to cut the BB and the plastic sheeting to the exact dimensions I needed. Using the template guaranteed each piece would be exactly the same.

I rough-cut the two BB pieces and the two black plastic sheets into rectangles that were 1/8" larger in each dimension than the template. I marked each piece with an arrow which would indicate the front of the piece, and I made sure the arrows on the template and the arrows on each piece were aligned before machining.

I used double-sided template tape to secure each piece to be routed to the template. With this done, routing each piece took only a couple of minutes.

I set aside the plastic pieces and glued the two BB pieces together, making sure the arrows were pointing in the same direction. After gluing, I measured in 1/2" from each side of the piece to delineate where the internal cavity would be. I then used a 3/4" spade drill bit to drill out each corner. Finally, I used a jig saw to cut along the lines to hollow out the internal cavity.

Next, I drilled holes for the power switch and the LED power indicator, and milled slots in the back for the audio cable and the USB power cable. Additional milling was also required for mounting the power switch (as can be seen in the photos). After a bunch of sanding, the result is shown in **Photo 1**. I finished up by staining the BB with a dark walnut stain.

I then turned my attention to the top and bottom smoked plastic pieces. First, I used some 120 grit sandpaper to soften the edges of the plastic because they were very sharp as a result of the milling.

Machining the top was easy as I only needed to locate holes for the six flat

head brass wood screws which would hold it on. I countersunk the screws so the heads would be flush with the surface of the plastic.

The bottom is just a little more complex because in addition to the mounting screws (which were done identically to the top), I had to drill holes to mount the RPi. Four 4-40 by 1" machine screws, 1/8" spacers, and nuts were used to mount the RPi.

With all of the machining and staining completed, I mounted the RPi onto the bottom plastic piece, glued a color changing RGB LED power indicator into place, mounted the power switch, inserted the 2 GB microSD card I had prepared previously, and then screwed the bottom assembly onto the enclosure. I attached four cork adhesive pads to the bottom as feet to protect whatever surface the music player was set upon.

Wiring was performed according to the simple schematic shown in **Figure 2**. I super-glued the electrolytic capacitor to the bottom plastic (noting polarity) and wired up the power connections, including the modified USB cable used for power.

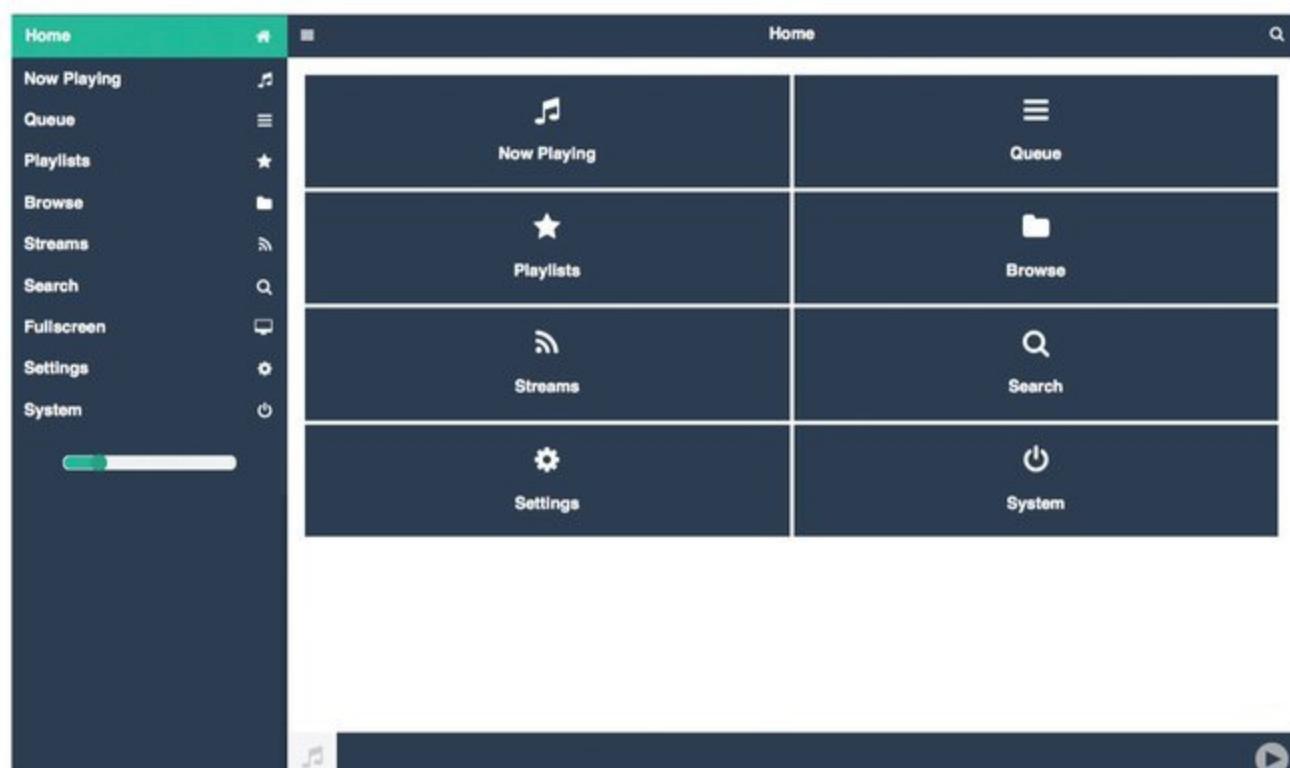
With the wiring completed, I plugged an audio cable into the USB sound module, connected up my USB power module, and then put the top into place and screwed it down. Assembly was now complete and the player was looking good.

Flipping on the power switch caused the rainbow power indicator to light, and I could see the RPi's power and activity indicators flashing through the translucent plastic, indicating the RPi was booting.

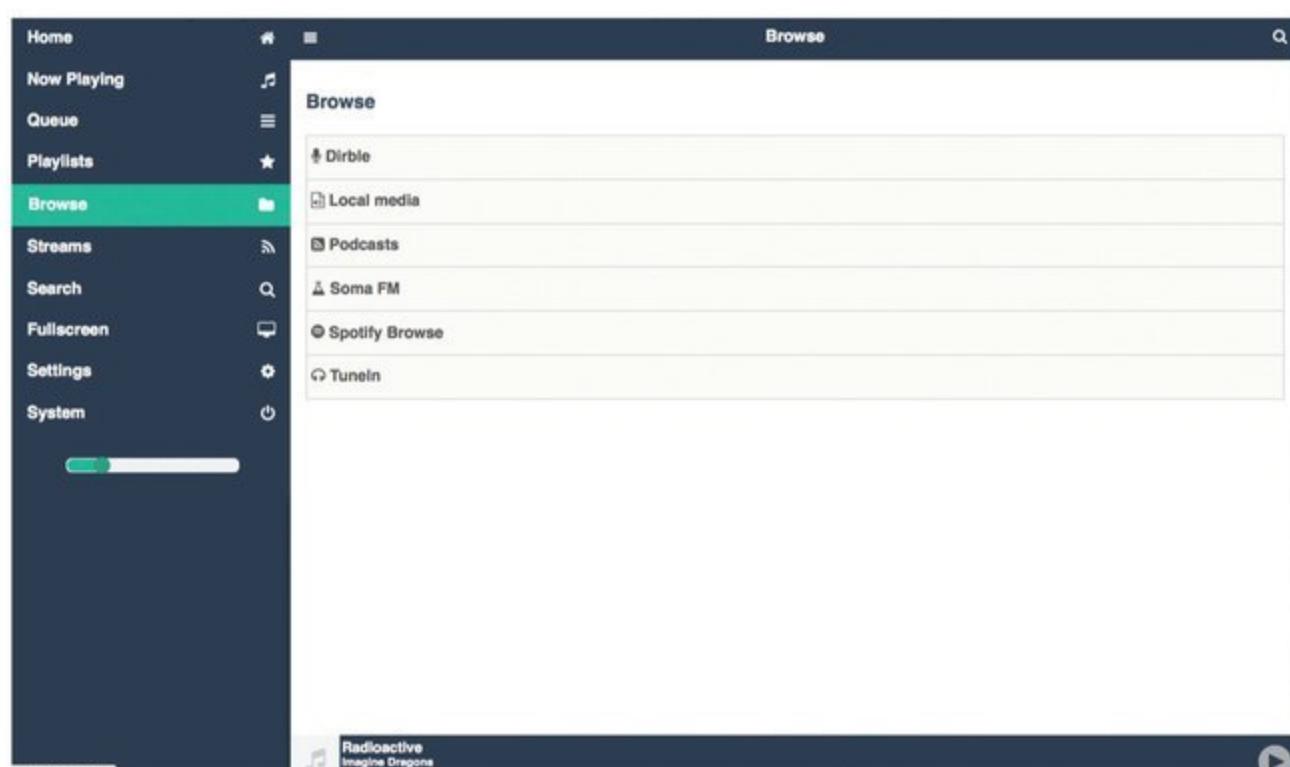
## Using the Music Player

Booting the music player takes a couple of minutes. During that time, there will be numerous clicks and pops sent out the audio connection, so it is best to allow the player to boot completely before turning on or turning up your connected stereo system. I always wait until I can access the player with a web browser before turning on my stereo.

Once the player is up, you can access it by typing "musicbox.local" or by typing the IP address your home router assigned into your browser's address bar. Once connected, you should see a screen like **Figure 3**. By clicking the Browse tab (**Figure 4**), you can navigate to either your local music collection, your networked music collection, select one of the many streaming sources, or select from a vast array of Internet radio stations via



**Figure 3.** Pi MusicBox Main Screen.



**Figure 4.** Pi MusicBox Browse Screen.

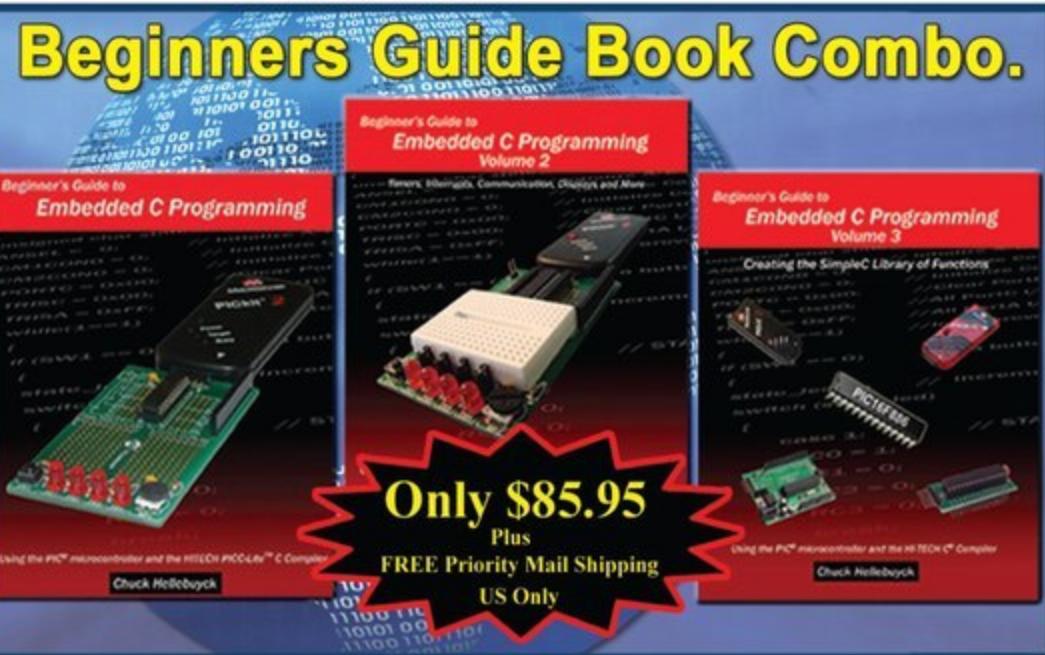
Tuneln, for example.

From the web user interface, you can control volume and selection of what music you want to hear. You can also control if the music should be played in a loop, and whether songs should be played sequentially or in random order.

## Music in the Back Country

My wife and I have a little retreat we often visit that has no cell phone service or Internet. It does, however, have electricity. We have a small stereo system that we hook an iPod to that provides music for us while we are visiting.

This has worked fine, but it is somewhat inconvenient in that we cannot control the music selection or volume from a different room. We have since replaced the iPod with this music player and it works great.



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To do this, however, I had to modify the software running on the RPi to support an Ad-Hoc network. What this means is the Music Player creates its own Wi-Fi network, allowing another Wi-Fi enabled device to connect to it wirelessly. Configuring an Ad-Hoc network is beyond the scope of this discussion, but for those interested, the information I used is available at <http://lcdev.dk/2012/11/18/raspberry-pi-tutorial-connect-to-wifi-or-create-an-encrypted-dhcp-enabled-ad-hoc-network-as-fallback/>.

With an Ad-Hoc network set up, I can use my iPod Touch's browser to control the music player. Note: Since there is no Internet available, I cannot listen to Internet radio stations. However, with over 500 CDs available on the 64 GB Flash drive built into the device, I never lack for music. Why not build one of these music players for yourself? NV

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# How to Craft a PIC Barometer

By Thomas Henry

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Of all the ingredients making up a local weather forecast, perhaps the most important is knowing what the current atmospheric pressure is doing. "Highs" and "lows" and especially rapid changes between those extremes typically give a very good indication of what's in store. The barometer — a device dating back to the time of Galileo — is used to measure atmospheric pressure. Until quite recently, barometers were mechanical in nature, built of siphons, glass cylinders or rubber bulbs filled with water, mercury, or air. Nowadays, we have electronic equivalents which are not only easier to use and more accurate, but also less expensive. Best of all, a solid-state barometric pressure sensor can be interfaced to a microcontroller for automated data logging and analysis of trends.

**T**he BMP085 – produced by Bosch Sensortec – is just such a device. This eight-pin marvel is exceedingly accurate, yet priced to be within easy reach of the most frugal DIYer. Communication with the chip is by way of the popular I<sup>2</sup>C bus, meaning that we can concentrate almost exclusively on manipulating the data it sends, rather than fussing over how to receive the data in the first place. As icing on the cake, the BMP085 also contains an integral thermometer. Not only is knowing the temperature useful to us humans, but the value detected also automatically figures into the barometric pressure measurement.

If you're a weather junkie like me who's always wanted a decent barometer which doesn't break the bank, then read on! In this article, you'll learn how to interface the BMP085 to most any PIC microcontroller. After covering the electrical requirements, we'll unravel the somewhat nasty software aspects (don't worry – all of the ugly mathematics and tricky data type manipulations have been taken care of for you). With what you learn here, you'll be all set to design a customized barometer and start making your own weather forecasts.

One final thing before we tuck into the details. Using the BMP085 with an Arduino is a breeze since software libraries already exist for it, but going with a microcontroller chip instead has a number of advantages. The PIC16F1825 that I used costs about one-tenth of an Arduino. Moreover, the required program code runs half as long.

Finally, with a PIC you get total control of the design at a much lower level. When you throw in the fact that we'll be using a free compiler to create the firmware, we're talking a complete high performance barometer for about ten smackers!

## Hooking It Up

The BMP085 is a tiny device (about a quarter inch square) intended for surface-mount construction. I don't know about you, but my eyes and hands are way too old to deal with such things. Fortunately, the component is readily available already soldered to a breakout board from a number of suppliers. See **Figures 1** and **2** which show the front and back.

This nifty affair features standard 0.1" pin spacing, meaning that it's easy to socket on a circuit board or try out on a solderless breadboard. I got mine for some six bucks from Amazon, but if you shop around you'll find it for even less

on eBay. Just so you know, you might also bump into the BMP180 (and breakout board) which is a newer version of the thing. The hardware and software described in this article are compatible with either.

Apart from making the chip more conducive to hand construction, the breakout board sports two other features to really help things along. First, you need to know that the BMP085 is a 3.3V device, but frequently (as with the circuit described herein) you'll want to use it with a 5V microcontroller. Conveniently, the breakout board comes loaded with a regulator and appropriate decoupling capacitors to derive the required lower voltage.

It was mentioned above that communication with the chip proper is by means of the relatively straightforward I<sup>2</sup>C bus, which is a two-wire affair. If you've played with this protocol at all, then you'll already know that the two lines comprising it – called SCL and SDA – each require a pull-up resistor. These, too, are provided on the breakout board.

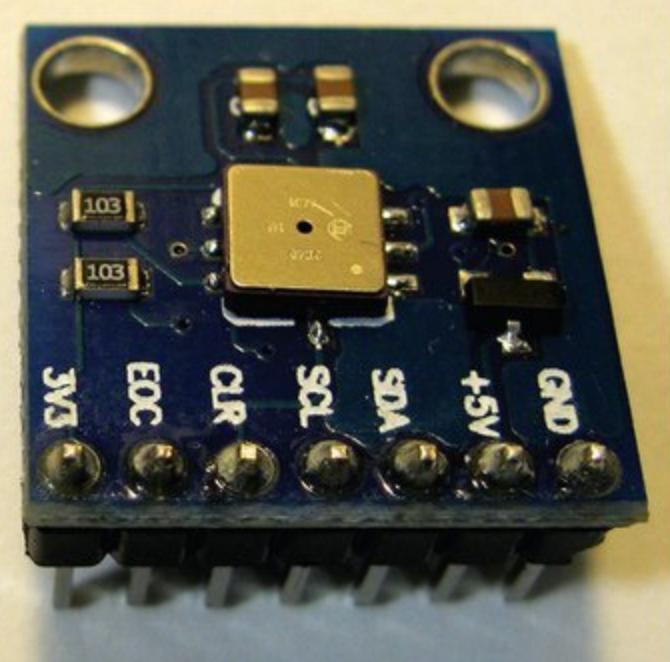
Now, one thing might worry you at this point. If the microcontroller is powered by 5V and the BMP085 by 3.3V, are we cruising for a bruising on the I<sup>2</sup>C bus with incompatible clock and data voltages? Not at all. One of the excellent features of this protocol is that the bus lines are configured around open-drain FETs. Instead of forcing pins high (to a possibly hazardous voltage for the BMP085), instead we're only safely bringing them low through those pull-up resistors just pointed out.

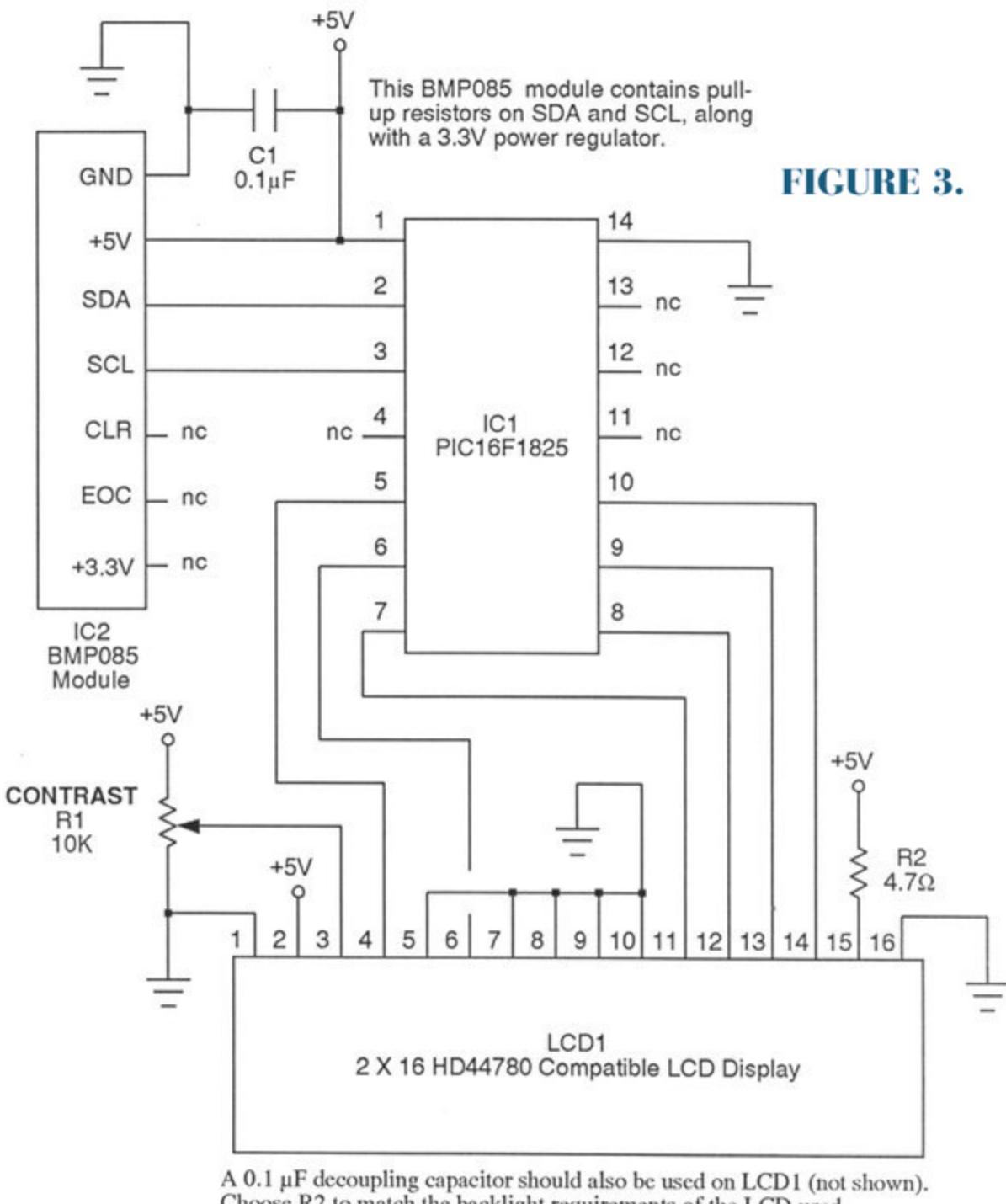
We've come this far, so let's go ahead and see the

**FIGURE 1.**



**FIGURE 2.**





So, you've got your PIC barometer up and running; now what? Here are a few guidelines to get you started on your weather journey.

First off, as a rule it's the change in values that matters most, not the absolute reading at any given moment. Keep in mind that atmospheric pressure varies naturally somewhat during the day due to assorted environmental or geographic factors. So, don't hover around the barometer taking constant readings. A more meaningful approach is to sense the atmospheric pressure once every 24 hours, say at 8:00 in the morning or 8:00 at night when the effects of the day's heating are under wraps. In this way, you'll see the big picture unsullied by little peaks and valleys which may mean nothing.

The following interpretations are widely quoted and reproduced on the Web, and are a good place to begin. The predictions are for the weather to expect in the next 24 hours. The numbers shown represent the mean sea level pressure measured in inches of mercury.

#### Over 30.20"

- Rising or steady
- Slowing falling
- Rapidly falling

- Continued Fair
- Fair
- Cloudy, Warmer

#### 29.80" to 30.20"

- Rising or steady
- Slowing falling
- Rapidly falling

- Same as Present
- Little Change
- Precipitation Likely

#### Under 29.80"

- Rising or steady
- Slowing falling
- Rapid falling

- Clearing, Cooler
- Precipitation
- Storm

complete circuit for a test rig. Refer to **Figure 3**. An LCD has been tacked on and that's about it so, really, no parts list is needed. Keep in mind that there are still four port lines free for additional features you might dream up.

For example, one could add on a real time clock, humidity sensor, warning beeper for rapid pressure changes, maybe even a stepper motor with indicator needle to imitate how an analog barometer might appear. In the words of the old Steve Allen song, "this could be the start of something big!"

When we get to the firmware in just a moment, you'll find that only half of the program space has been consumed, with a plentiful 4,000 words left over for new features.

Oh, and software I<sup>2</sup>C routines ("bit-banging") have been exploited throughout, meaning that you can connect the sensor to most any port lines of any PIC you want, as long as they support both input and output modes.

## Bits, Bytes, Words, Integers, and Longs

The time has come to consider the program which orchestrates the show. The code has been written in Great

Cow Basic – my tool of choice when working with PIC and AVR microcontrollers. This excellent compiler is open source and free of charge, yet is a genuine powerhouse. It features many, many valuable commands and data types, and is exceedingly easy to use. If you don't already have it, you can download a copy from [gcbasic.sourceforge.net](http://gcbasic.sourceforge.net). As long as you've got the computer warmed up, go ahead and fetch the software for this article from the article link, too.

First off, let's get a feel for how the BMP085 pulls off its magic. When the circuit of **Figure 3** is first powered up, the PIC queries the barometer for some calibration data. These are 11 16-bit factory-set constants, personalized to each and every unit manufactured. The calibration constants need only be fetched once at power-up. They'll be used in some later computations to fine-tune the reading. We'll wind up with temperature accurate to one decimal place and the atmospheric pressure to two decimal places.

After that, the BMP085 is polled once every second or so for the current readings. We'll receive both the uncompensated temperature and atmospheric pressure along the I<sup>2</sup>C bus.

Next, some basic arithmetic is wielded to convert

those numbers into accurate compensated values, then we'll conclude by printing the results to the LCD.

The datasheet for the BMP085 is a good one and details the computations necessary. They're very easy to handle if you're just going to carry them out with pencil and paper. I won't lie to you, though. Creating the PIC code to perform those calculations consumed over 100 hours of my life and was one of the most difficult programming challenges I've ever faced. Here's why.

Of the 11 calibration constants mentioned a moment ago, some of them represent signed 16-bit integers, while others are unsigned integers — also 16-bits. (The signed version is called an *integer* in Great Cow Basic, while an unsigned one is a *word*.) What's more, in the actual computations, some of the intermediate subtotals are also mixed up like that. Then, toss in the fact that when divisions occur, sometimes the quotient should be rounded and at other times simply truncated. It was an incredibly frustrating two weeks of very full days sorting this all out. It pleases me to no end that I can spare you that! With the software library included with this article, you can start using the BMP085 within minutes.

Here's how I handled the mixed data types. All of the 16-bit numbers (constants and variables alike) — whether signed or unsigned — are promoted to 32-bit numbers, which Great Cow Basic calls *longs*. No need to worry about overflows now! Furthermore, with one consistent data type throughout, keeping things straight is much simpler. **Figure 4** explains what's going on behind the curtain, should you be curious.

However, a new problem arises. In the Great Cow compiler, 32-bit arithmetic is always assumed to be performed on unsigned longs. So, I had to forge ahead and write new multiplication and division routines to accommodate signed long integers. (Addition and subtraction take care of themselves). For ultimate accuracy, I also created a division routine which rounds things properly when needed. Incidentally, all of the computations are easily handled without recourse to floating point arithmetic. Why open a can of beans with a stick of dynamite?

To see how it all shakes out, be sure to look over the "BMP085.H" include

**FIGURE 4.**

*Example:*

*To represent -1234 in two's-complement form:*

0000 0100 1101 0010

Start with the positive number 1234.

1111 1011 0010 1101

Then complement it.

+1

Finally, add 1.

1111 1011 0010 1110

equals -1234

↑ sign bit is set, meaning negative

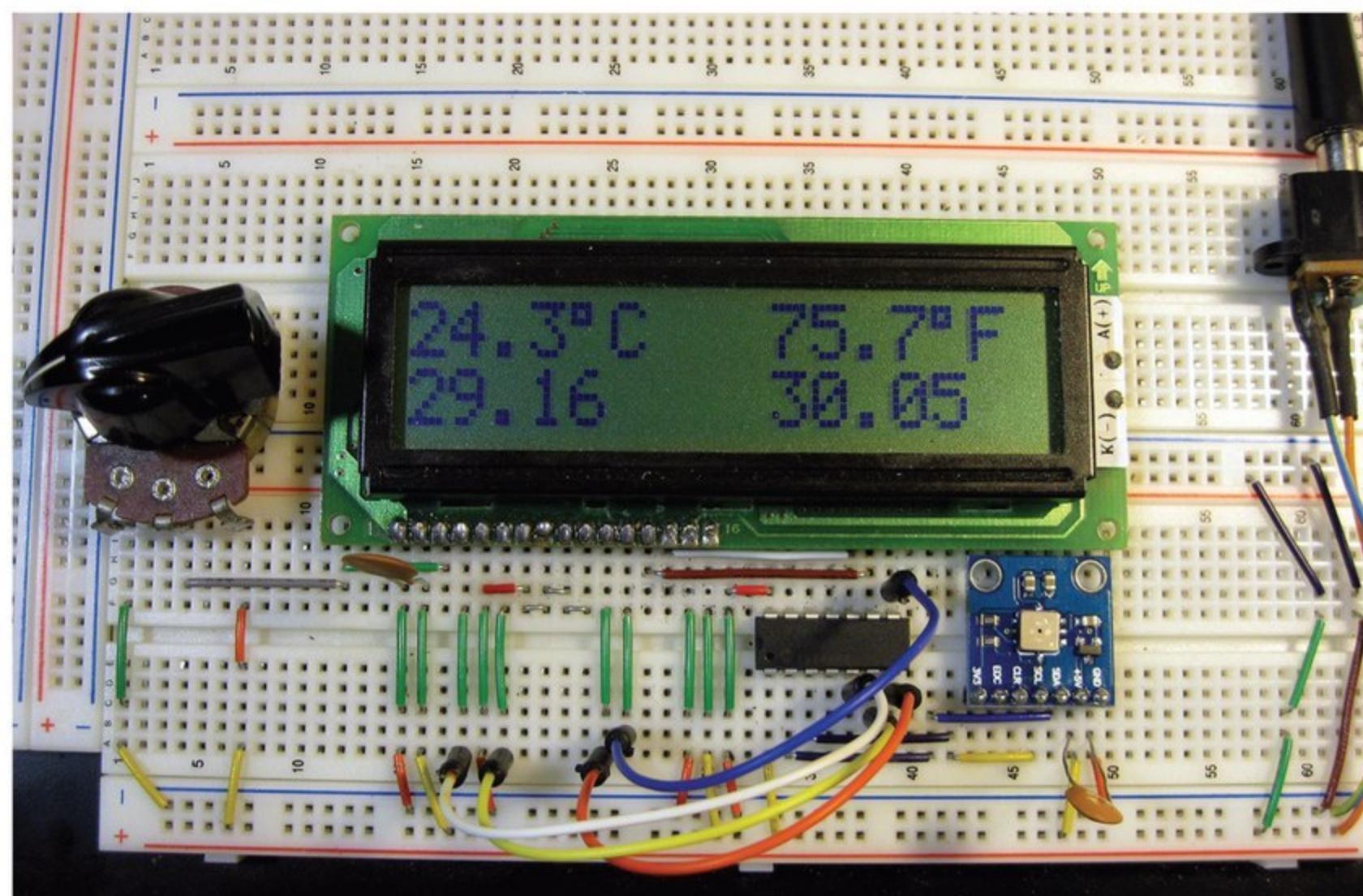
The integer type as shown here is 16-bits long. To cast it to a 32-bit, long integer, prefix the number with sixteen additional 1's, since it's negative. Were it non-negative, it would be prefixed with sixteen additional 0's.

file which contains the library routines and is heavily commented throughout.

## ***And Finally, the Firmware***

By including the file "BMP085.H" in your own programs, you now have access to three commands — no muss, no fuss:

**FIGURE 5.**



- `getConstants()`
- `getTemp(Celsius, Fahrenheit)`
- `getPressure(Pascals, Station, MSLP)`

Now's the time to mention that the BMP085 spits out the atmospheric pressure in *Pascals* — a member of the so-called International System of Units. If you live in the United States, you'll probably find the traditional inches-of-mercury (inHg) scheme more familiar. The firmware takes

care of making this conversion. But there's more!

The sensor reads the actual or absolute atmospheric pressure of wherever it is sitting — whether you live in a cave far below the surface of the earth or on top of a mountain. This is referred to as *station pressure*.

On the other hand, newspapers and television broadcasts report readings in what's called *mean sea level pressure*, abbreviated *MSLP*. The station pressure is converted and standardized to what it would be if you lived at sea level. This makes it easier to compare values and trends over vast regions of the earth.

Clearly, *MSLP* depends upon the elevation of where you're living. I visited City Hall and found the value for my very block from one of the kindly civil engineers there.

In the source code, you'll note the constant *BMP\_PRESS\_FACTOR* and how to set it based on your elevation. If it isn't clear, the `getPressure` command in the library file returns values for all three systems: Pascals, station pressure, and *MSLP* (the latter two in inHg).

Solid-state barometers tend to bounce around a little compared to mechanical types which, in effect, exploit inertial averaging. To mitigate this, the BMP085 has four different levels of operation governed by what the manufacturer calls the "over-sampling setting." It's really nothing more exotic than finding the mean of several consecutive readings.

Provision is made for taking averages of one, two, four, and eight samples, and this is set by the constant *BMP\_OSS* (with a value of 0, 1, 2 or 3, respectively). If you look into the code, you'll find other niceties, along with various hints, tips, and explanations.

**Figure 4** shows my test rig cranking along. In the top row of the display, the temperature is given both in Celsius and Fahrenheit. The bottom row shows the station pressure and the *MSLP*.

With that, you should be all set to begin crafting your own barometer with the BMP085. May your forecasts ever come true! **NV**

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# A DIY Indoor Air Quality Monitoring System

By Tom Kibalo

Most of us spend much of our time indoors. The air that we breathe in our homes and work areas can put us at risk for health problems. Understanding and controlling some of the common pollutants can help improve your indoor air quality, and reduce yours and your family's risk of health concerns related to air quality.

There are some excellent guides on this available from the US Environmental Protection Agency, but an important step in this process is to begin to monitor your indoor air environment.

Given the availability of inexpensive gas sensors, gas monitoring for the DIY enthusiast is readily attainable. As a result, we decided to build our own gas monitoring prototype system using ISaAC (a Raspberry Pi adapter board introduced back in the *Nuts & Volts* August 2014 issue) and a Raspberry Pi. ISaAC seemed like a natural fit based upon its ease of use with the Raspberry Pi – especially in this type of measurement and control application. We finally ended up with a monitoring air quality

measurement system capable of collecting, measuring, and recording selected indoor air gas pollutant concentrations and the ability to report pollutant levels in real time, while allowing long term logging of concentrations to understand both trends and to facilitate rework/validation for any notional remedies. The resulting prototype system is portable enough for easy deployment to isolated areas of a house including the basement, garage, bedroom, attic, etc.

In this article, we will discuss the prototype system design, our sensor selections, and the approach we used on how to apply specific manufacturer's specifications to derive gas concentration levels. Let's get started!

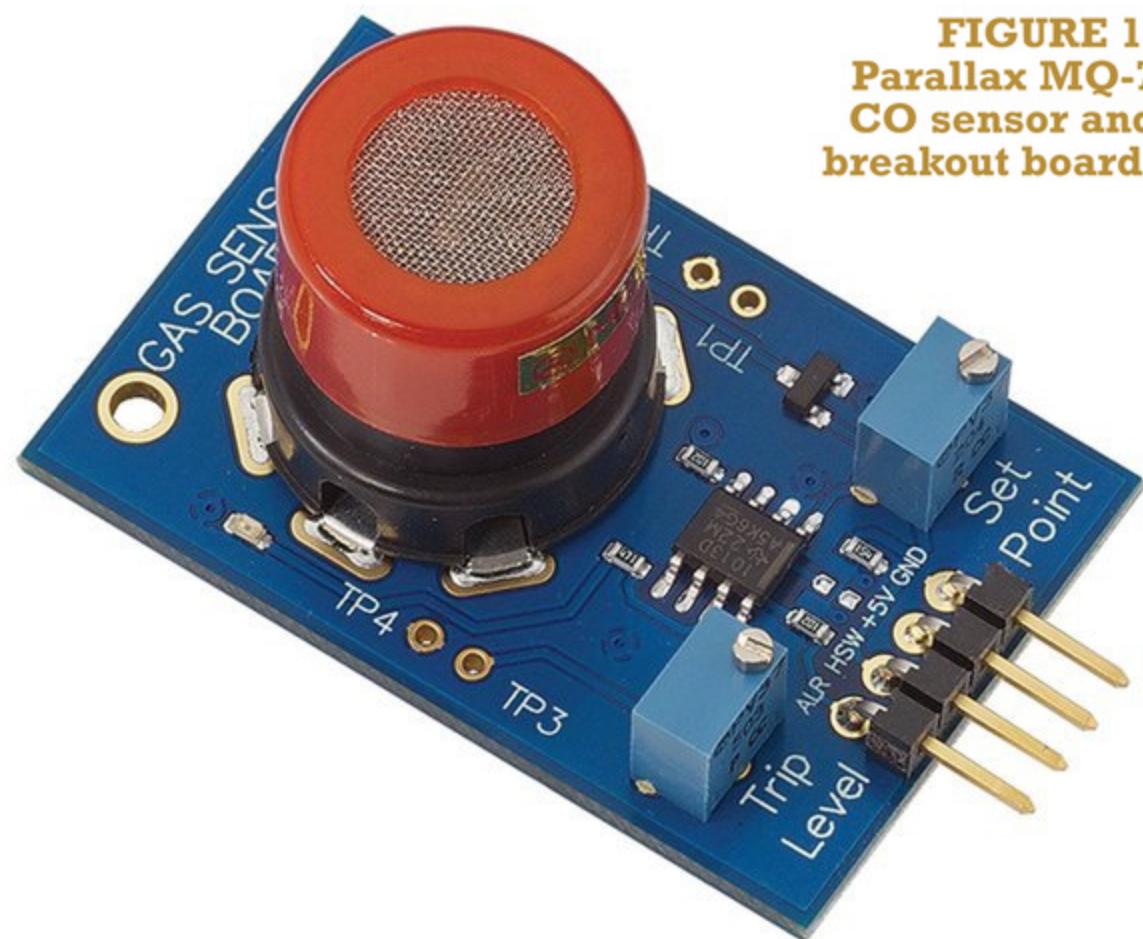
## The Indoor Air Pollutant Environment and Our Sensor Choices

- Carbon monoxide (CO) is a colorless, odorless gas that interferes with the delivery of oxygen throughout the body. CO causes headaches, dizziness, weakness, nausea, and even death. (Ivan Blumenthal, [www.ncbi.nlm.nih.gov/pmc/articles/PMC1281520](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1281520).)
  - Sensor Chosen: MQ-7 CO 50-3,000 PPM Parallax gas sensor board (see **Figure 1**).
- Volatile organic compounds (VOCs) are chemicals found in paints and lacquers, paint strippers, cleaning supplies, varnishes and waxes, pesticides, building materials and furnishings, office equipment, moth repellents, air fresheners, and dry-cleaned clothing. VOCs evaporate into the air when these products are used, or sometimes even when they are stored. (P. Wolkoff, et. al. <http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0668.1997.t01-2-00003.x/abstract>).
  - Sensor Chosen: GROVE HCHO 1-50 PPM Grove gas sensor board (see **Figure 2**).
- Combustion pollutants are gasses that come from fuel-burning appliances. The amount depends on the appliance, and how well it is installed, maintained, and vented. Fuel types also vary; typically, propane and methane. In my case, we use propane for our kitchen stove and gas fireplace. (A. Kazragis, A. Gailius, [www.tandfonline.com/doi/abs/10.1080/16486897.2006.9636893#.VH6AfDHF9qs](http://www.tandfonline.com/doi/abs/10.1080/16486897.2006.9636893#VH6AfDHF9qs)).
  - Sensor Chosen: MQ-2 combustible gas and smoke 300-10,000 PPM Grove gas sensor board (see **Figure 3**).

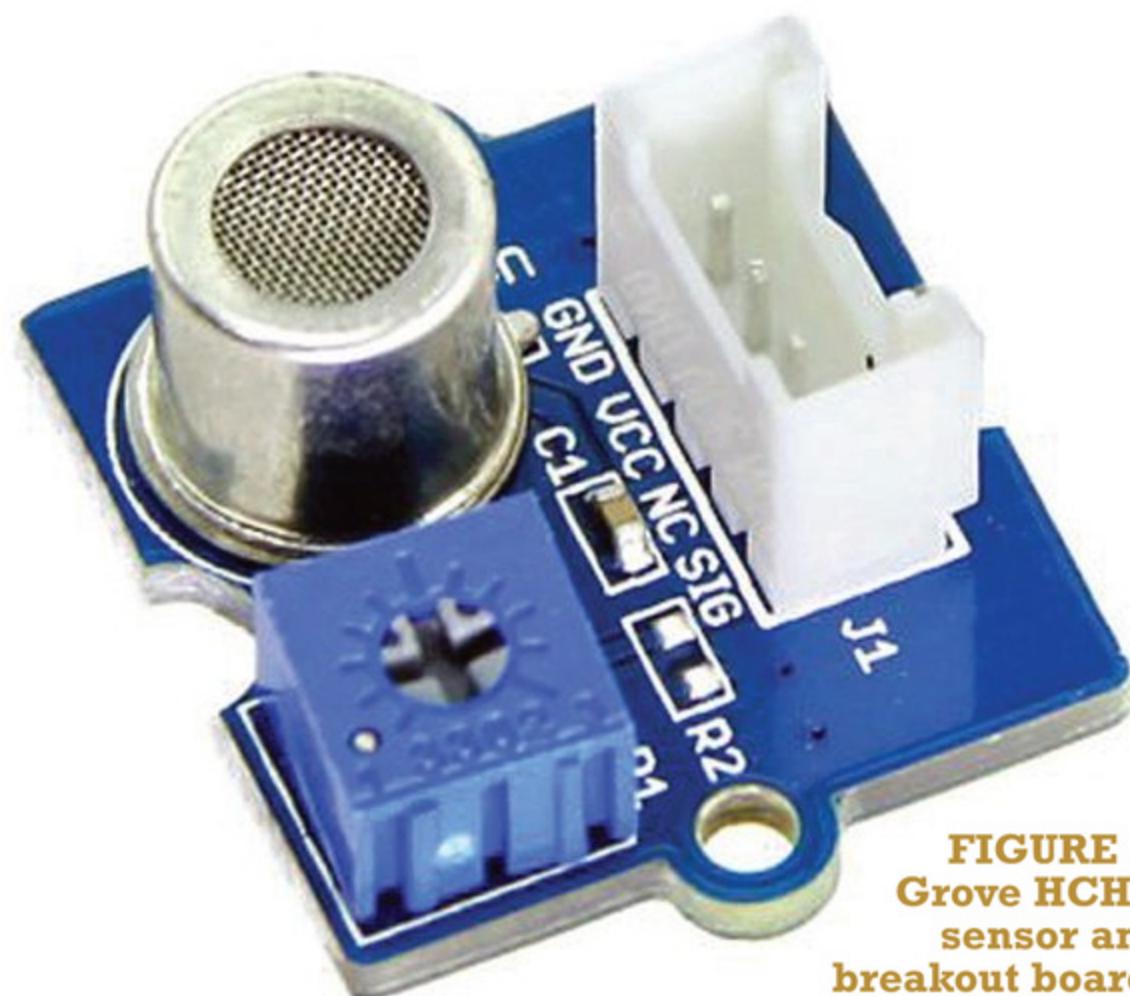
## Background and Theory in Applying a Gas Sensor

Gas sensors are widely available for various gas types, sensitivity levels, and different cost factors. All of the MQ sensor series are inexpensive (MQ-7 CO, HOCHO, and MQ-2 LPG) with reasonable PPM (PPM stands for one part per million) resolution. This sensor series uses a small inside heater in conjunction with an electro-chemical sensor. The heater allows for good sensitivity against a range of gasses that occur indoors at room temperature.

The preferred sensor wiring is to connect both sensor 'A' pins together and both sensor 'B' pins



**FIGURE 1.**  
Parallax MQ-7  
CO sensor and  
breakout board.



**FIGURE 2.**  
Grove HCHO  
sensor and  
breakout board.



**FIGURE 3.**  
GROVE MQ-2  
LPG sensor and  
breakout board.

together (see **Figure 4**). The A and B pins are driven by a common voltage (VCC). A picture of this sensor and a general circuit of the MQ sensor is shown in **Figure 5**. The schematic shows a resistor network for the sensor (RS) in series with the load (RL) to ground. The gas sensor output voltage is VRL – the voltage across RL. From the schematic (using the Kirchhoff voltage law), it can be shown that:

$$RS = \left( \frac{V_{cc}}{VRL} - 1 \right) \times RL$$

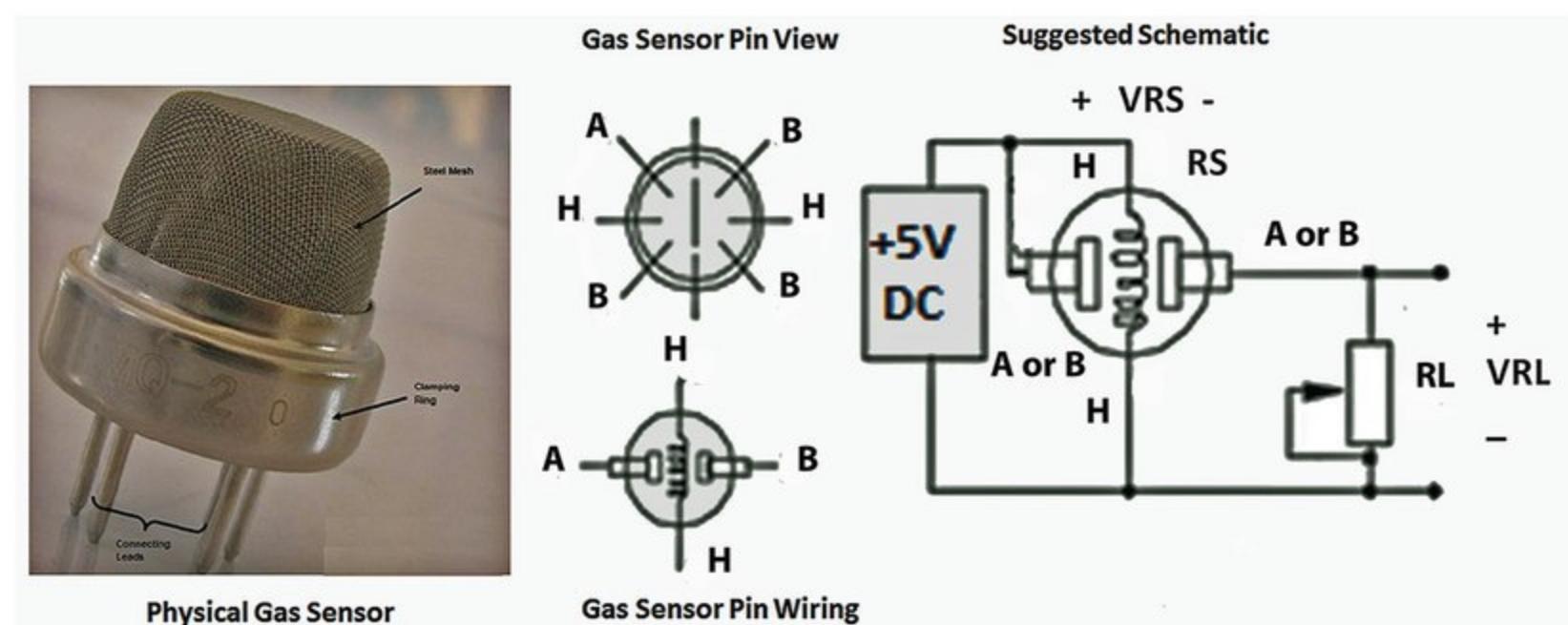
All of our MQ sensor breakout boards incorporate RL as a settable potentiometer and +5V as VCC. It should be no surprise with a lower RL there is a lower VRL value, resulting in less resolution in measurement. Likewise, the higher the VRL value, the greater resolution we have for similar concentrations of gas.

There is a notable exception to the heating scheme with the MQ-7 CO. It requires a two-cycle VCC heater voltage: first, applying +5V to purge the sensor for 60 seconds; and then +1.4V for 90 seconds to perform before measurement. Fortunately, the Parallax breakout board has an on/off transistor that allows for the heater voltage to be changed using Pulse Width Modulation (PWM). More on this later.

Let's examine a typical MQ spec. The manufacturer's spec sheet for all MQ sensors uses a graph indicating gas sensitivity of a sensor as a ratio of RS (sensor resistance) to R0 versus PPM (refer again to **Figure 5**).

This RS/R0 ratio is a linear relationship across different gas concentrations when using a log scale for RS/R0 versus gas PPM. Generally, PPM is the lowest unit of measurement, where 10,000 PPM = 1% by volume.

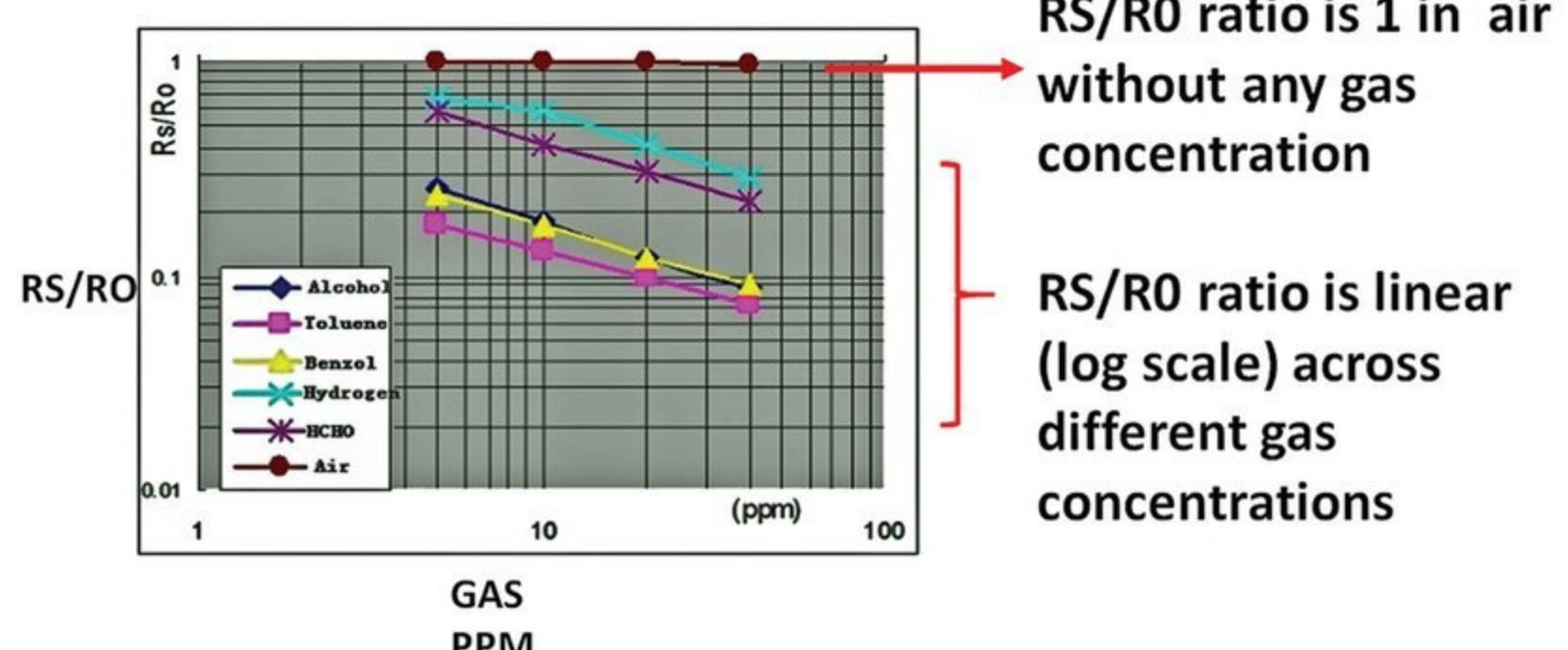
Note that within the graph there is a pure air condition where RS/R0 = 1. This is an important relationship in our PPM determinations. Let's review the following steps to understand the process of determining PPM from VRL:



**FIGURE 4. Generic gas sensor.**

1. Fix the VCC (+5V).
2. Fix and measure your RL (in pure air) for necessary sensitivity (use manufacturer recommendations).
3. Measure corresponding VRL for pure air conditions.
4. Derive RS (pure air) using the equation shown previously.
5. Look up the RS/R0 ratio for pure air conditions using the MQ graph.
6. Calculate R0 using the ratio. We now have a fixed R0 to use for PPM determination.
7. Once we've completed steps 1 to 5, we are in a position to calculate PPM from VRL samples.
  - a. Measure VRL with our computer system.
  - b. Use VRL to derive RS (step 4).
  - c. Look up the RS/R0 ratio (step 5).
  - d. Calculate R0 (step 6).
  - e. Look up gas PPM using RS/R0.

Although steps 6 and 7 seem straightforward, they can be cumbersome. There are a number of discrete equations to solve, and the manufacturer's graph can be



**FIGURE 5. Manufacturer's spec: RS/R0 versus PPM for MQ-2.**

large and unwieldy for lookup within a software application. We can automate the process by using a spreadsheet to plot and thus capture the curve fit for the RS/R<sub>0</sub> relationship to VRL and then to PPM. A simple regression can be used to derive a formula. The formula can then be applied for code use within Python. As an example, with MQ-2, the equation is  $y = 0.1575e^{1.724x}$  where LPG gas PPM is  $y$  and the MQ-2 VRL is  $x$ . The spreadsheet example is shown in **Figure 6**.

Most of this spreadsheet “leg work” has been done for you on the selected gas sensors, and the necessary equations are derived. A copy of this spreadsheet with the gas equations is available for download at the article link.

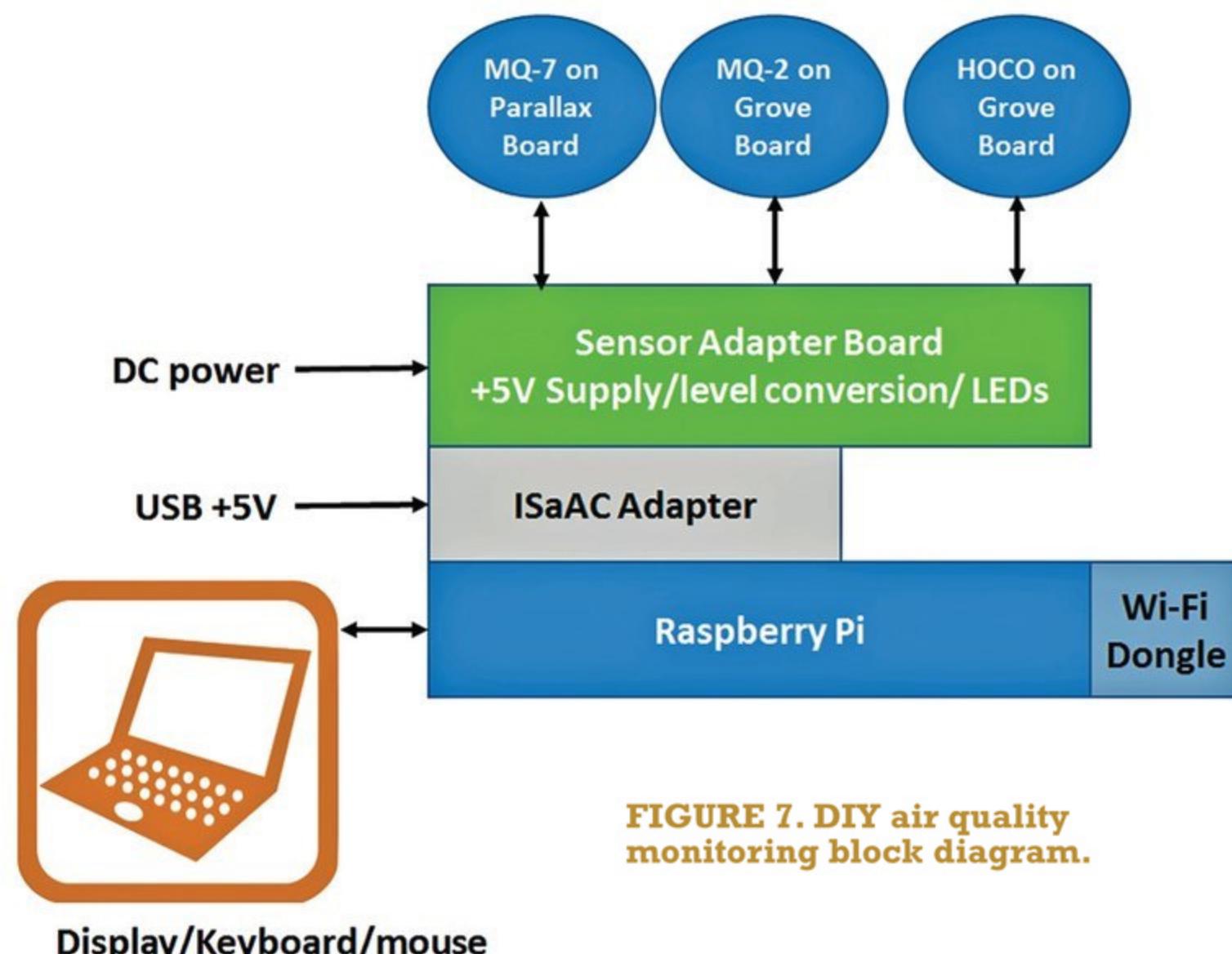
As you build your own air quality prototype using the equations (**Figure 6**), keep in mind several fixed required conditions before starting:

Concentration Look Up	ratio lookup	Calculated	Plot VRL	Plot PPM
Concentration PPM	R <sub>s</sub> /R <sub>0</sub>	R <sub>s</sub>	VRL	Concentration PPM
5	0.19	13066.8	2.01176	5
10	0.14	9628.15	2.37152	10
20	0.09	6189.53	2.88799	20
40	0.07	4814.08	3.16357	40

Clean Air Calculation				
V <sub>r</sub> l (measured)	R <sub>L</sub> (set)	VCC (measured)	R <sub>S</sub> (cal)	R <sub>S</sub> /R <sub>0</sub>
0.648	10240	5	68772.3	1
			68772.3	

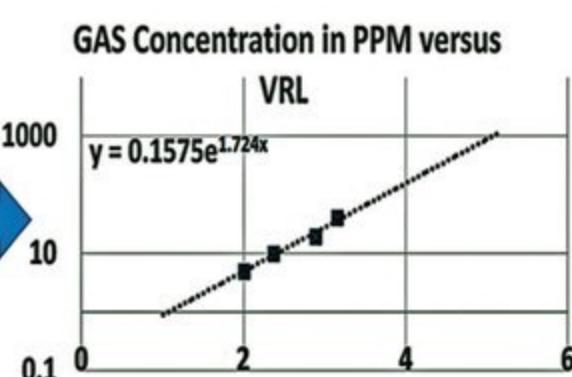
**FIGURE 6.** Excel MQ-2 derived PPM to VRL equation.



1. Configure RL on breakout boards; these can be set using a multimeter when VCC power is not applied to the boards. In our case, we followed manufacturer's specifications and configured both MQ-2 and MQ-7 for an RL of 10K, and HCHO for an RL of 20K.
2. Keep the supply voltage (VCC) to +5V DC.

## Prototype Overview

Let's start with a good old fashioned block diagram (see **Figure 7**). The computer hardware, as mentioned earlier, is based on an ISaAC adapter/Raspberry Pi board. The application is written in Python which executes on the Raspberry Pi. To this, we added a gas sensor interface board. This is where the MQ-7, MQ-2, and HCHO sensor breakout boards interface directly to computer hardware. The sensor board also provides an LED feedback.



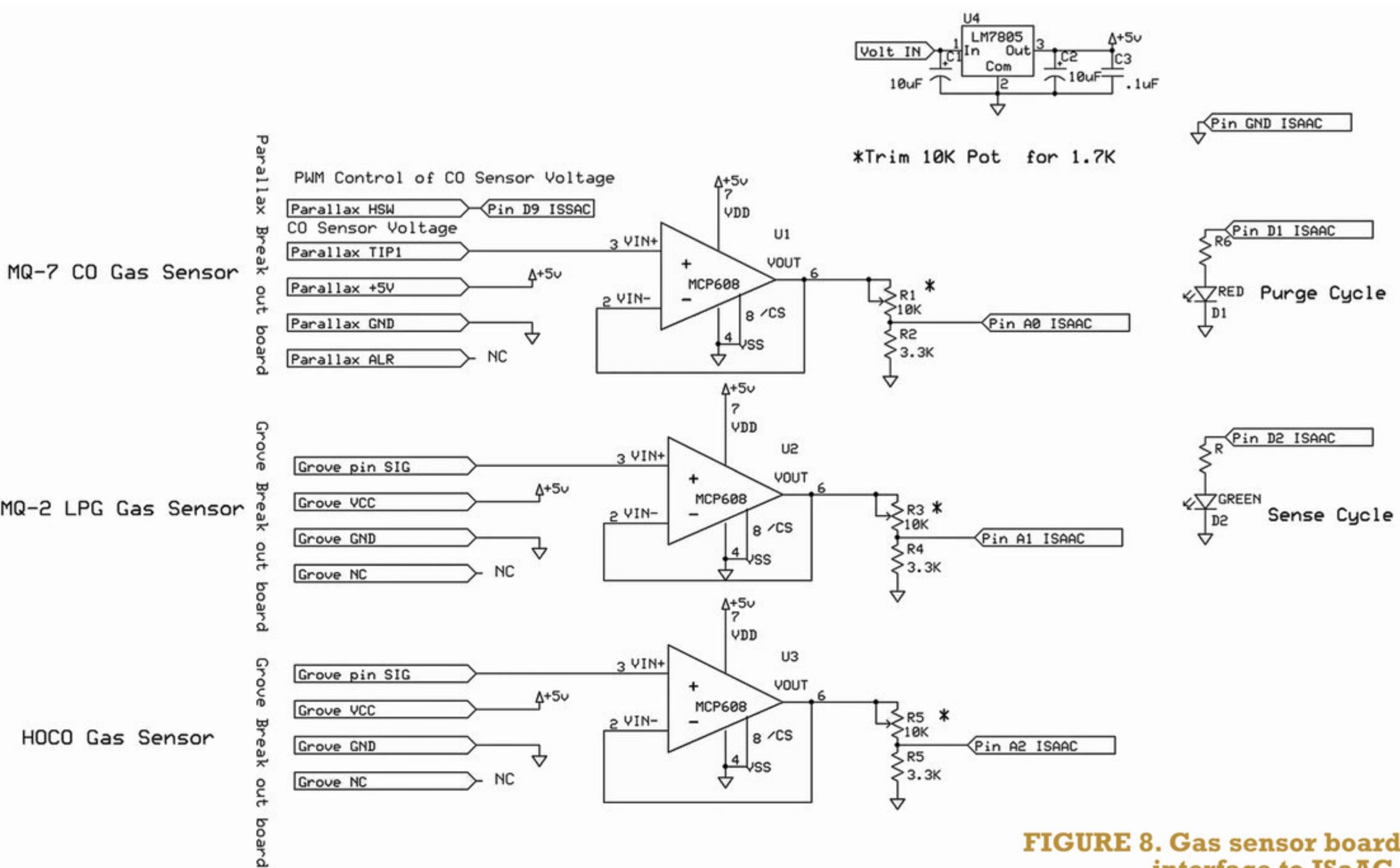
The various gas sensor breakout boards are supplied with +5V DC power and ground from our sensor interface. Also, it is here where the sensor voltage outputs are buffered and levels are converted for ingestion into the computer hardware.

As noted earlier, each sensor contains individual heating elements that at +5V require current. These typically run hot, and can consume about 160 mA each. It is not practical to use power from the ISaAC and Pi; +5 volts is needed to supply heater power, so a separate +5V DC supply is integrated in the sensor interface to handle all gas sensor power.

Finally, for email connectivity, the system uses a Wi-Fi dongle or direct Ethernet connection.

## Sensor Board Particulars

The MQ-2 and VOC sensor use a fixed +5V. The MQ-7 CO sensor is unique from the other sensors in that it requires the use



**FIGURE 8.** Gas sensor board interface to ISaAC.

of PWM to switch from +5V (sensor purge 90 second cycle) to +1.4V (sensor measurement 60 second cycle). The Parallax sensor breakout board provides an HSW input to switch the MQ VCC on/off. We use the HSW with PWM control to achieve the +1.4V and +5V VCC needed for this sensor.

The sensor board also uses three Microchip MCP608 rail-to-rail op-amps to do a voltage level conversion from the native sensor +5V peak analog to the ISaAC/Pi +3.3V peak requirements.

The op-amps connect directly to the VRL sources from the breakout boards, and then each outputs to a resistor network of a 10K pot in series with a 3.3K resistor to ground. The pot settings are about 1.7K to achieve a full scale conversion of +5V to +3.3V at the tap point of each resistor network. These networks prevent overdriving of the input 3.3V analog pins of ISaAC, thereby protecting them (see the sensor interface schematic in **Figure 8**).

ISaAC does the “heavy lifting” of interfacing to the gas sensor boards, as well as driving the LEDs – all under Python control by the Raspberry Pi. The ISaAC Python library is used for this control in commanding the hardware:

- **API\_ADC (pin)** to do 10-bit analog-to-digital conversions where pin is 14 (A0), 15(A1), and 16

(A2) for MQ-7, MQ-2, and HCHO.

- **API\_com (command string)**

- For digital I/O where various command strings are OXX (set out digital), HXX (set digital high), and LXX (set digital low) for XX = 01, 02 for D1, and D2, respectively.
- For precision PWM using command string ‘Z’ + ‘09’ (pin D9) + 5 digit PWM frequency (HZ) + 6 digit PWM duty cycle (microseconds).

## Resources

Various:  
 (3) 10K Potentiometer  
 (3) 3.3K Resistor  
 (2) 1K Resistor  
 (1) Red LED  
 (1) Green LED  
 (1) Raspberry Pi with Display, Keyboard, Mouse

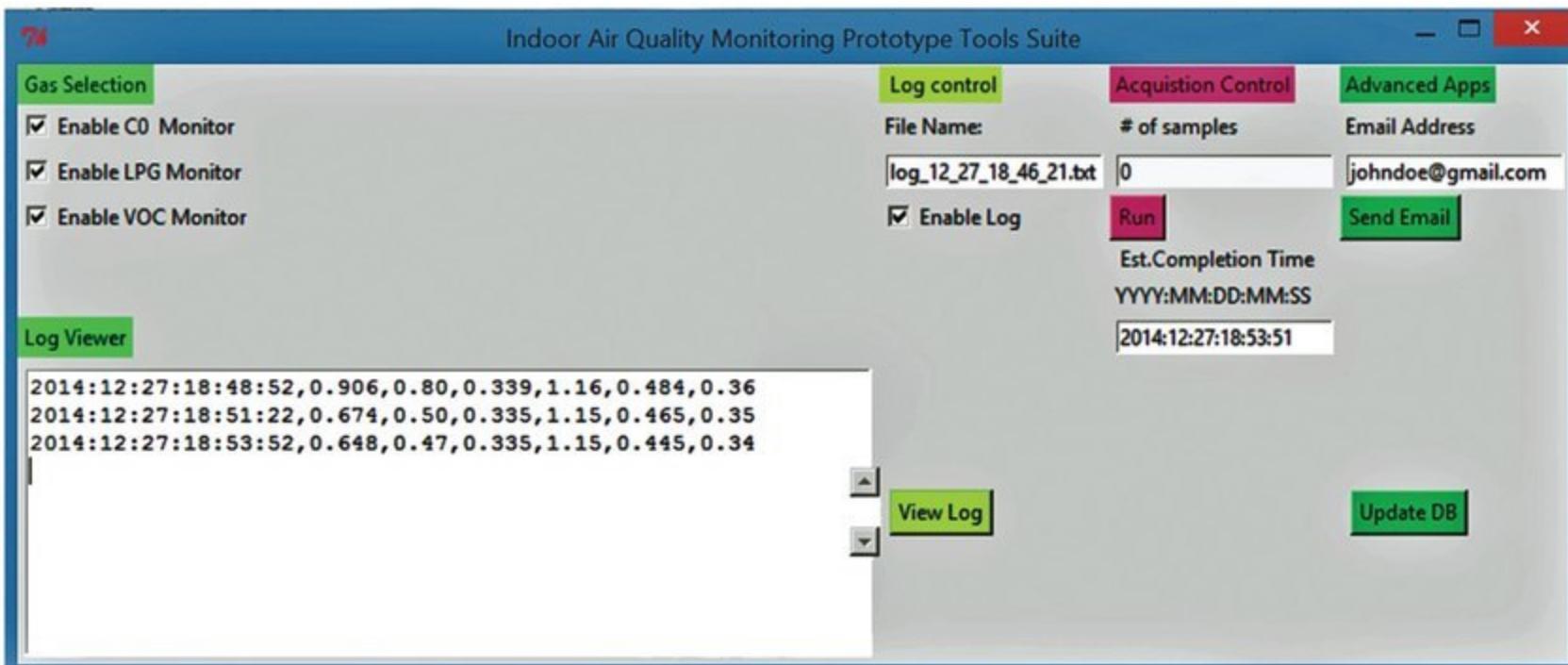
[www.nutsvolts.com](http://www.nutsvolts.com)  
 (1) ISaAC board

[www.kibacorp.com](http://www.kibacorp.com)  
 Free Downloads IsAAC Software and Documentation

[www.parallax.com](http://www.parallax.com)  
 Gas Sensor Board (#27983)  
 CO (Carbon Monoxide) MQ-7 Gas Sensor (# 605-0007)

[www.seeedstudio.com](http://www.seeedstudio.com)  
 Grove Gas Sensor MQ-2 LPG  
 Grove HCHO Sensor

[www.microchip.com](http://www.microchip.com)  
 Microchip Direct (3) MCP-608 Op-Amp eight-pin DIP



**FIGURE 9.** Air quality monitoring GUI.

Gas sensor collection and measurement occurs once every 150 seconds for the duration of the collection session. This is dedicated by the number of total samples requested. Each 150 second collection cycle is marked by a red LED active for the purge cycle, followed by a green LED for the measurement cycle.

## Prototype Operation

The air quality system application is implemented using Raspberry Pi Python 2.7 code with ISaAC, Tinker, and SMTP, MYSQL, and File I/O Python libraries. Once the application is launched under IDLE, a Monitoring and Control GUI appears similar to what is shown in **Figure 9**. The application was kept simple and built to help DIYers understand and evaluate these new gas sensors for indoor environments.

Measurements made during the application process are automatically time tagged, converted to voltage, and if optionally logged, PPM. The data can be maintained using an MYSQL database to support analysis and trending.

Let's clarify what is meant by a sample in our system. A sample is a collection of all selected gas measurements (both voltage and calculated PPM). It is comma delimited and terminated with a carriage return and line feed. Each sample starts with a full date/time string tag that captures the start time of the first gas value in the sample.

The sample is ASCII formatted as follows (voltage and PPM are in decimal): YYYY:MM:DD:MM:SS, CO voltage, CO PPM, LPG voltage, LPG PPM, VOC voltage, VOC PPM, CR, LF. If a gas is not selected, then a blank will exist between the appropriate commas.

A good way to understand the application's functionality is to walk through the application's applied use of the Python Tinker GUI widget set and its associated features. Notice, first of all, that the GUI display is broken into four main sections: Gas Selection, Log Control, Acquisition Control, and Advanced Control.

Let's start with Gas Selection. Here, check boxes help you select which of the three sensors are candidates for measurement.

The next section (Log Control) provides a file name where the session measurements will be stored (if the Enable Log checkbox is selected). If it is not selected, the session will simply dump all the measurements into the Python shell for direct viewing.

Acquisition Control sets the number of samples for the collection session. The user sets this by typing a sample number in the Entry box. Upon hitting the "Run" button, an estimated completion time is automatically displayed and logging commences if enabled. The application will automatically set a file log name in the File Name entry box. The file name uses the measurement start time as an example: Gas\_Log\_YYYY\_MM\_DD\_MM\_SS.txt.

With each sample collected by the system, the sample's number box will decrement, and the collection session will end at the zero sample.

Once the session ends, a user can view the file log by hitting the "View Log" button. The file log content appears as a scrollable text box widget. Under Advanced Control, the log results can be stored in an MYSQL database (gas\_database.db) for long term archival by hitting the "Update DB" button.

The user can also elect to send a copy of the log file using the "Send Email" button to the recipient's email address listed in the email entry box address. The "from address" in this email will be fixed to your DIY air monitor system.

When in doubt about what is going on, examine the outputs that are printed to the Python Shell; it captures all the action going on "under the hood." That is about it for operation — simple enough!

## Software Installation

A Python bundle for the entire system is available for download at the article link. Just unzip within your main Python folder and you should see:

- ISSACCOMVER2.PY (ISaAC Library)\*
- GASGUIVER11.PY (main application operation and GUI)
- SYSMAIL.PY (email function)\*\*
- SQLITE\_CREATE\_DB.PY (SQLITE database install)

Just run this once. It will create a relational database for log entries. The database table is named "GAS." In GAS, the entries are samptime, COVOLTS, COPPM, LPGVOLTS, LPGPPM, VOCVOLTS, and VOCPPM

- SQLITE\_LOG\_INSERT.PY. This code takes the current log file and loads its contents into the database.
- SQLITE\_EXAMPLE\_QUERY.PY. This is a query example to be run against the database once you have updated it with some log file data. It queries all COVOLTS>0. This is run independent of all other files, and serves as an example of what the database query can do for you (but does not represent the complete functionality). Please refer to Python SQLITE for a more complete set.
- The entire application launches under IDLE as the Python module GASGUIVER11.PY.

\*The ISaAC board needs to be integrated with the Raspberry PI GPIO serial port. The process is straightforward and appears in the August 2014 article mentioned earlier. It's detailed in the freely downloadable ISaAC Tech Manual.

\*\* SYSMAIL.PY needs to be updated with your personal email address and password. Placement variable definitions are provided in code.

## Current Prototype

**Figure 10** shows our current bench implementation.

As you can see, our version of the sensor board and its connections to ISaAC (sitting on top of the Raspberry Pi) uses a solderless breadboard. Again, simple enough. Since ISaAC implements an Arduino compatible form factor, one may choose a more compact implementation that could be realized by integrating all the sensor board electronics onto an Arduino shield.

The present configuration has been successively moved around my house and gas measurements have been collected. A substantial database of these recordings is now in place.

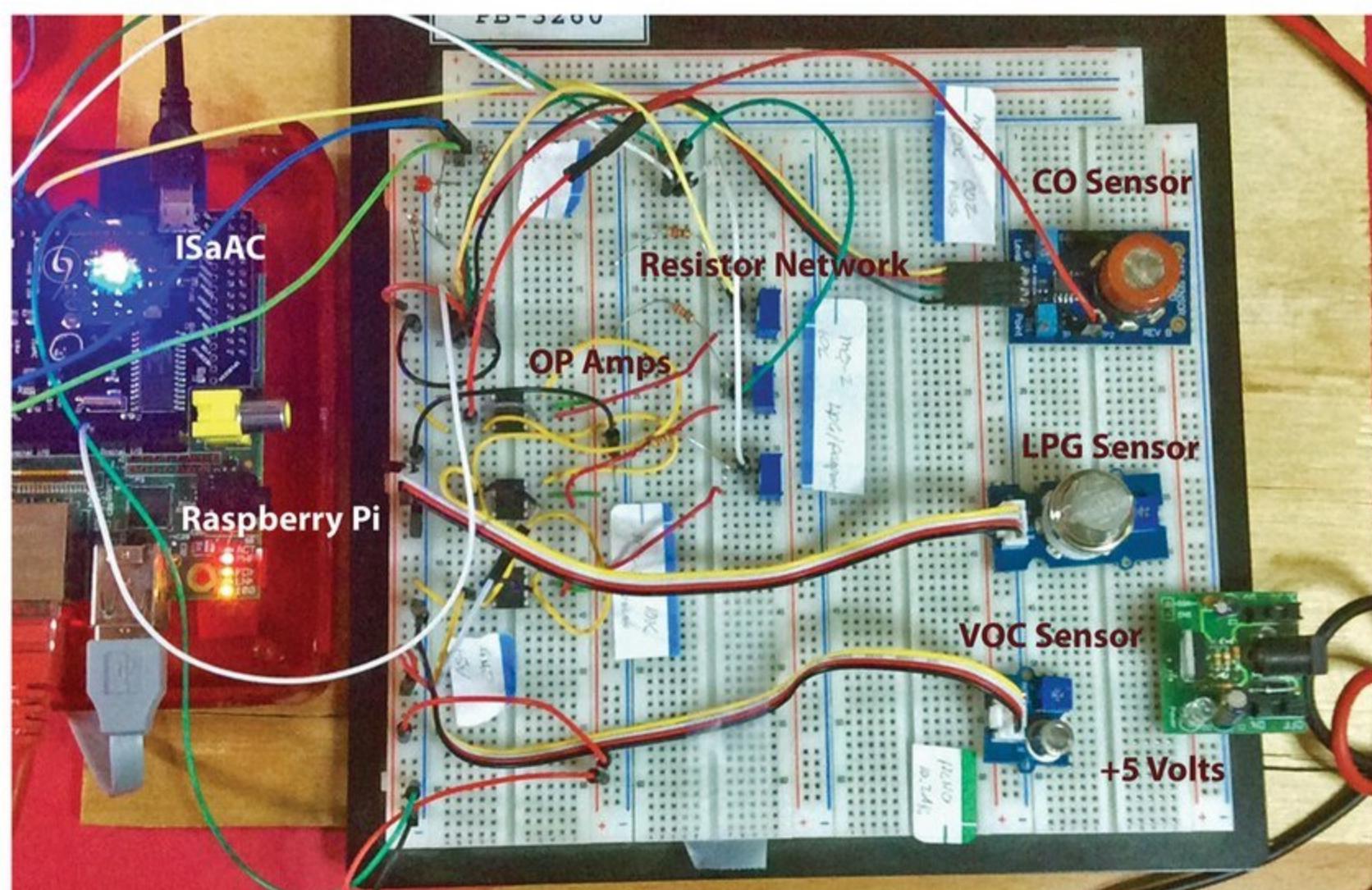
One area remaining to

be addressed is calibration. That will be an additional project. The literature indicates a number of ways in which this can be accomplished, so given that the entire design is open and readily modified, I'll leave that up to you. For my purposes, this current configuration captures what I need for now in terms of gas indications.

## What's Next?

In this article, we introduced you to tools and techniques to understand and apply gas sensors within an indoor environment. The hardware and software for this open implementation can serve as a model for your own DIY system. It is expandable, so you can first start with a single sensor and then add on the others. Our discussion on gas sensors should also help you apply other sensor types in your design.

Until next time, happy air monitoring! **NV**



**FIGURE 10.** Prototype air quality system.

# Giving Our "Board" Wings to Fly Over LANs or the Internet

Soldering is a perishable skill. So, every time I get a chance, I pick up a soldering iron and make some solder joints. I also love to lay out printed circuit boards (PCBs). That's because after I lay one out, I have to solder stuff to it. More times than not, there's a microcontroller on that PCB. That leads to having to hone my programming skills. So, I guess that means that I really love to design and build electronic gadgets. I'm especially fond of Ethernet-equipped gadgets because that most always forces a connection to another Ethernet-laden gadget over an LAN or the Internet. So, guess what we're about to do ...

## The "Board"

We will implement a flexible design for a multi-purpose 32-bit microcontroller-based platform. This model will be based on a six UART-equipped PIC32MX795F512L. One of the sextet of UARTs shall drive an FTDI FT232RL USB-to-serial IC. Another one of the PIC32MX795F512L's UARTs will be used to service a "true" RS-232 port, which will be overseen by an STMicroelectronics ST3232C RS-232 interface IC. A third PIC32MX795F512L UART will be pinned out

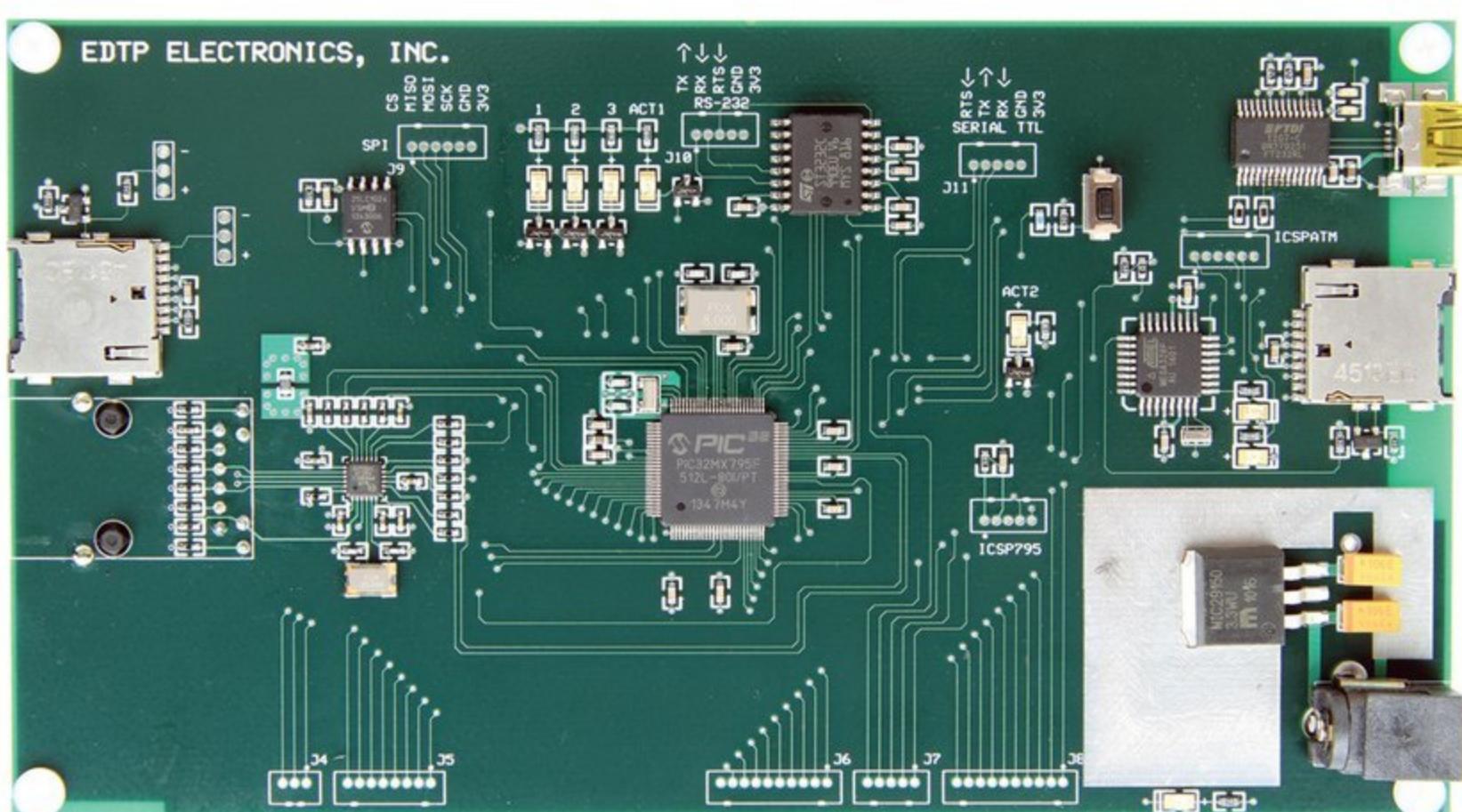
for general-purpose use. The fourth UART will act as a pipeline to a microSD card under the control of an Atmel ATmega328P.

In a previous Design Cycle (June 2015), we designed a microSD implementation that was capable of being driven by a PIC32MX795F512L. We'll "reuse" and include the details of that design in this month's project. The inclusion of the PIC32MX795F512L-driven microSD card allows us to utilize the microSD card portal for bootloading, web serving, and general-purpose data handling. The native microSD card interface will be

supplemented by a 1 Mbit 25LC1024 EEPROM.

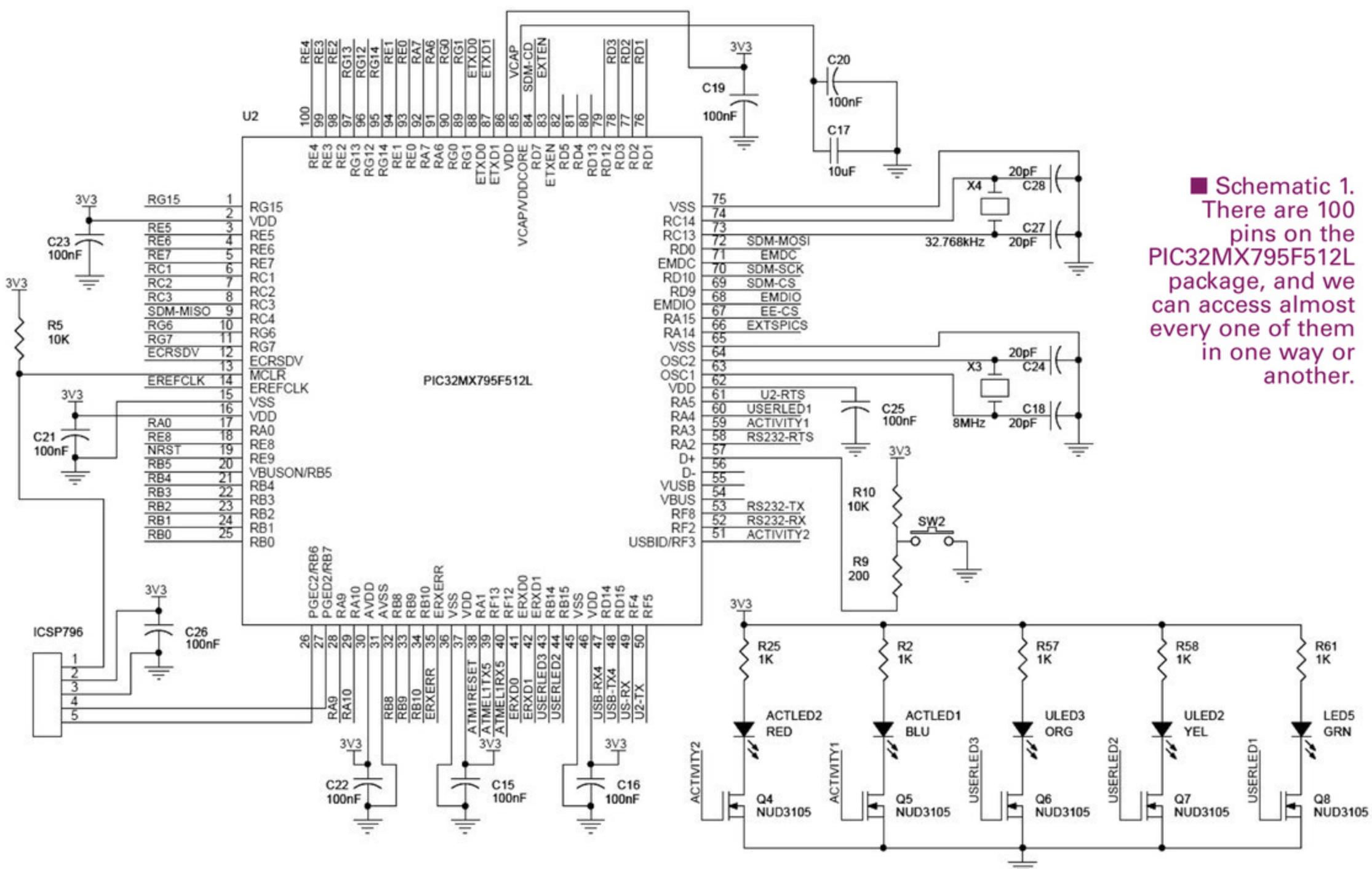
In that other Microchip SPI Flash memory ICs are pin-compatible, the EEPROM space can be occupied by a denser Flash memory device if necessary. Just in case we need to interface an SPI-based IC or peripheral to our PIC32MX795F512L, we'll also pinout a standard SPI portal.

What would any microcontroller-based design worth its salt be worth without LEDs? To offload our PIC32MX795F512L's I/O subsystem, we'll drive all



■ Photo 1. This little board allows you to send it, receive it, process it, and store it. You can do this via wired Ethernet or external wireless modules. What you don't see in the shot is the Ethernet magnetics package which is mounted on the opposite side of the PCB.

Post comments on this article and find any associated files and/or downloads at [www.nutsvolts.com/index.php?/magazine/article/august2015\\_DesignCycle](http://www.nutsvolts.com/index.php?/magazine/article/august2015_DesignCycle).



of our user-controllable LEDs through a NUD3105 MOSFET relay driver. The NUD3105 includes all of the necessary bias resistors and steering diodes on the chip. So, we don't have to mount the gate and drain resistors normally associated with standard MOSFET switch circuits.

The power supply design will be simple and rugged. A Micrel MIC29150 will provide a regulated +3.3 VDC power supply rail. The MIC29150 is capable of supplying up to 1.5A of current from input voltages as high as 26 VDC. This will allow us to power the circuitry from common wall wart power bricks.

The PIC32 was not only chosen for its large number of UARTs. This particular microcontroller also contains an on-chip Ethernet MAC and is capable of driving an external PHY device. In this case, our choice of external PHY devices is provided by Microchip in the form of the SMC LAN8720A. The addition of the LAN8720A gives our device the capability of web serving, acting as a TCP/IP client or server, and providing email (SMTP), time (SNTP), UDP, and FTP services.

Timing is always important when it comes to microcontroller circuitry. Time is also important to humans. To appease both human and silicon, the PIC32MX795F512L's internal RTCC (Real Time Clock and Calendar) will be attached to an external 32.768 kHz

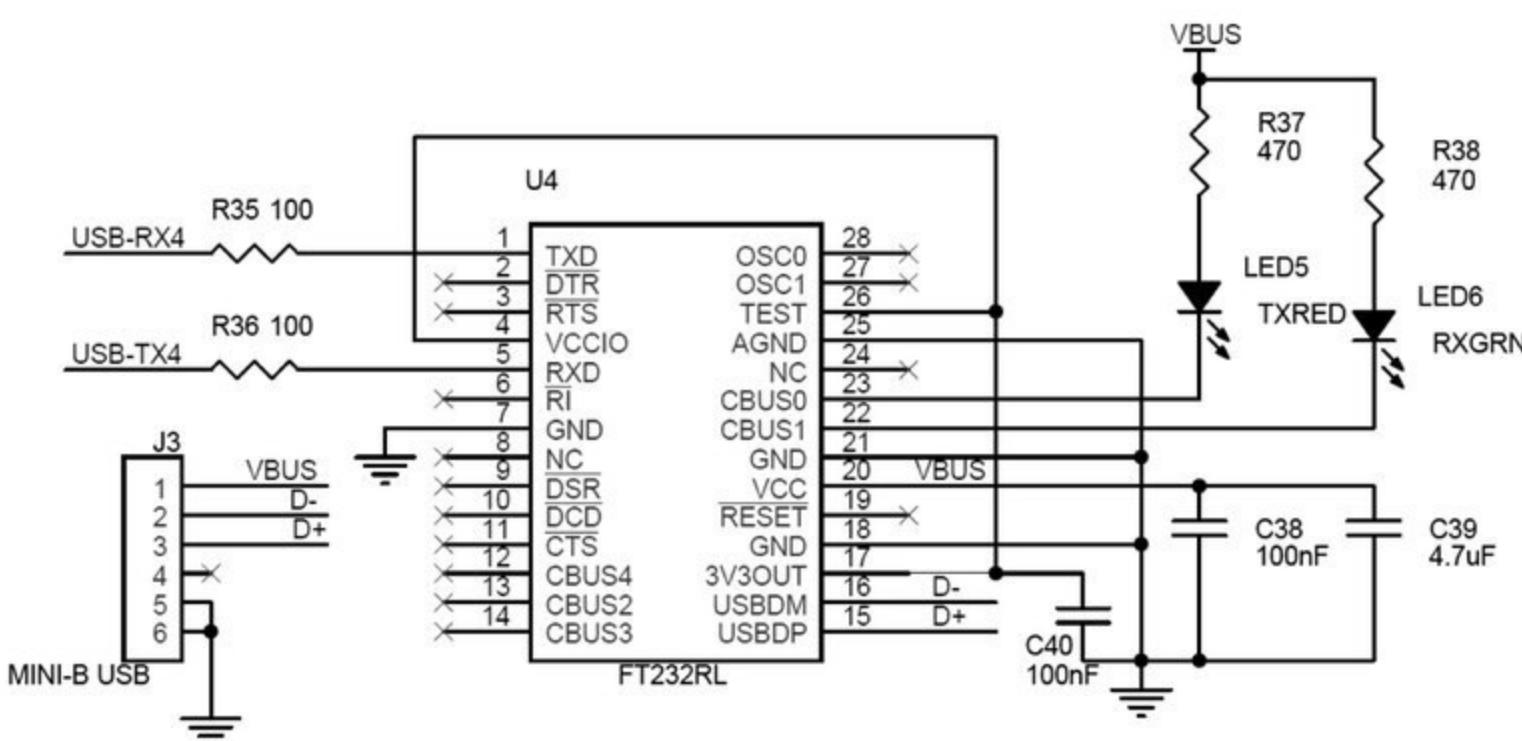
crystal. This will provide a real time clock that can be used for various timing requirements. For instance, the one second tick from the RTCC can be used to blink an "I'm alive" LED. The finished product is shown in **Photo 1**. To make the assembly you see in **Photo 1** possible, we had to combine and interconnect a number of electronic subsystems.

# The Heart of the System

**Schematic 1** is a graphical depiction of the PIC32MX795F512L and its supporting resistors, capacitors, crystals, switches, LEDs, and LED drivers. The 8 MHz CPU clock crystal is the seed for the PIC32's PLL, which ramps up the CPU clock frequency to 80 MHz. The PIC32MX795F512L's internal peripherals are also clocked at 80 MHz. Coupled with the PIC32's immediate I/O commands (LATxSET, LATxCLR, LATxINV), the 80 MHz clock makes for some very fast I/O switching.

You can also see how clean the LED NUD3105 MOSFET driver circuits are. All we have to do is connect an NUD3105 to its respective PIC32MX795F512L I/O line and write the code to drive it.

The NUD3105 also allows us to directly drive small relays in the same way we are driving the LEDs.



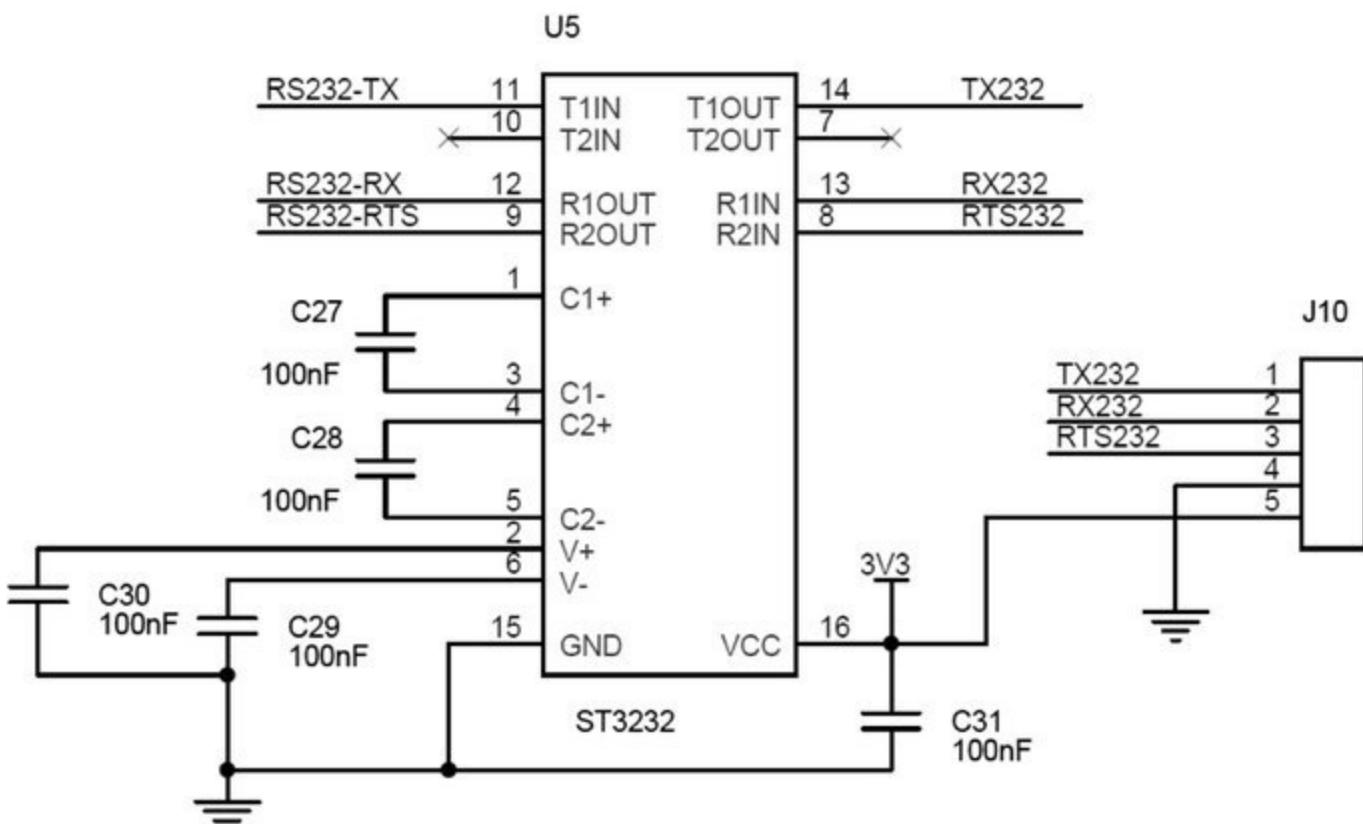
■ Schematic 2. There's not much to do here as far as the hardware is concerned. Tasks include filtering the supply voltage and taking care of the indicator LEDs.

In my opinion, many boards like our board have too many pushbuttons. The sole intent of designing in the single pushbutton switch was bootloading control. My first use of the pushbutton switch during development of the code for this column was in a debugging sequence. So, it's there if we need it for whatever we may need it for.

The PIC32MX795F512L is programmed and debugged using a PICkit 3, which is attached to our board's male five-pin ICSP connector using a six inch cable assembly terminated by a five-pin DF13 1.25 mm female header.

## USB in a Chip

The FT232RL is attached to the PIC32MX795F512L



■ Schematic 3. Setting up an RS-232 hardware port used to be a real pain. I remember back in the day having to lash up separate receiver and transmitter ICs that required negative supply voltages. Today's RS-232 interface ICs are a breeze to use.

via its transmit and receive lines. This module will most likely be used to communicate with a host USB device such as a laptop PC.

The only physical housekeeping we have to do here is make sure we don't over-current the indicator LEDs. The real work is in the firmware driver. You can view the FT232RL hardware details in **Schematic 2**.

## RS-232 is Not Dead

The news of the death of RS-232 has been greatly exaggerated. RS-232 interface ICs are not hard to find, and many modern devices are equipped with a legacy RS-

232 portal. So, why not include a true RS-232 portal on our board?

Like the USB subsystem, the RS-232 subsystem is not a burden on the hardware side of the fence. According to **Schematic 3**, we only need to add five 100 nF capacitors to the mix.

## microSD on a String

A slightly modified version of SparkFun's OpenLog is drawn up in **Schematic 4**. The original intent of the OpenLog was to simply store the incoming stream of RS-232 data on the microSD card. However, there are commands associated with the OpenLog that allow us to control the microSD card file system.

So, we can choose to use this microSD card to log data or store data under program control. The really neat thing about it all is that the control and data transfers are done via one of the PIC32MX795F512L's UARTs.

## microSD the Microchip Way

The "other" microSD card is being fed from one of the PIC32MX795F512L's SPI portals. Like the OpenLog microSD card, the "other" microSD card can be used to log data or store data under program control using Microchip's microSD card file system.

However, the microSD card under the control of the PIC32 also has the ability to hold firmware images that can be booted into the PIC32MX795F512L. Jumper blocks are used to set the card

detect logic level. In that the PIC32MX795F512L-controlled microSD card is seen as an SPI portal to the PIC32, there isn't much hardware work to be done in this area. The minimal "other" microSD card hardware setup can be seen in the contents of **Schematic 5**.

What you don't see in the schematic is the SPST switch between pins 9 and 10 of MSD95. The switch is an integral part of the microSD socket. When a card is present, the switch is closed.

The switch feeds the gate of the MOSFET. Depending on the

JumperX settings, the MOSFET is either turned ON or OFF by the state of the card detect switch. Normally, the gate of the MOSFET is tied high and the SPST switch within the microSD card socket is jumpered to go logically low when closed.

The 25LC1024 EEPROM signals are shared with the PIC32MX795F512L's microSD card. The EEPROM is selected using the PIC32's EE-CS I/O pin.

## All Powerful Ethernet

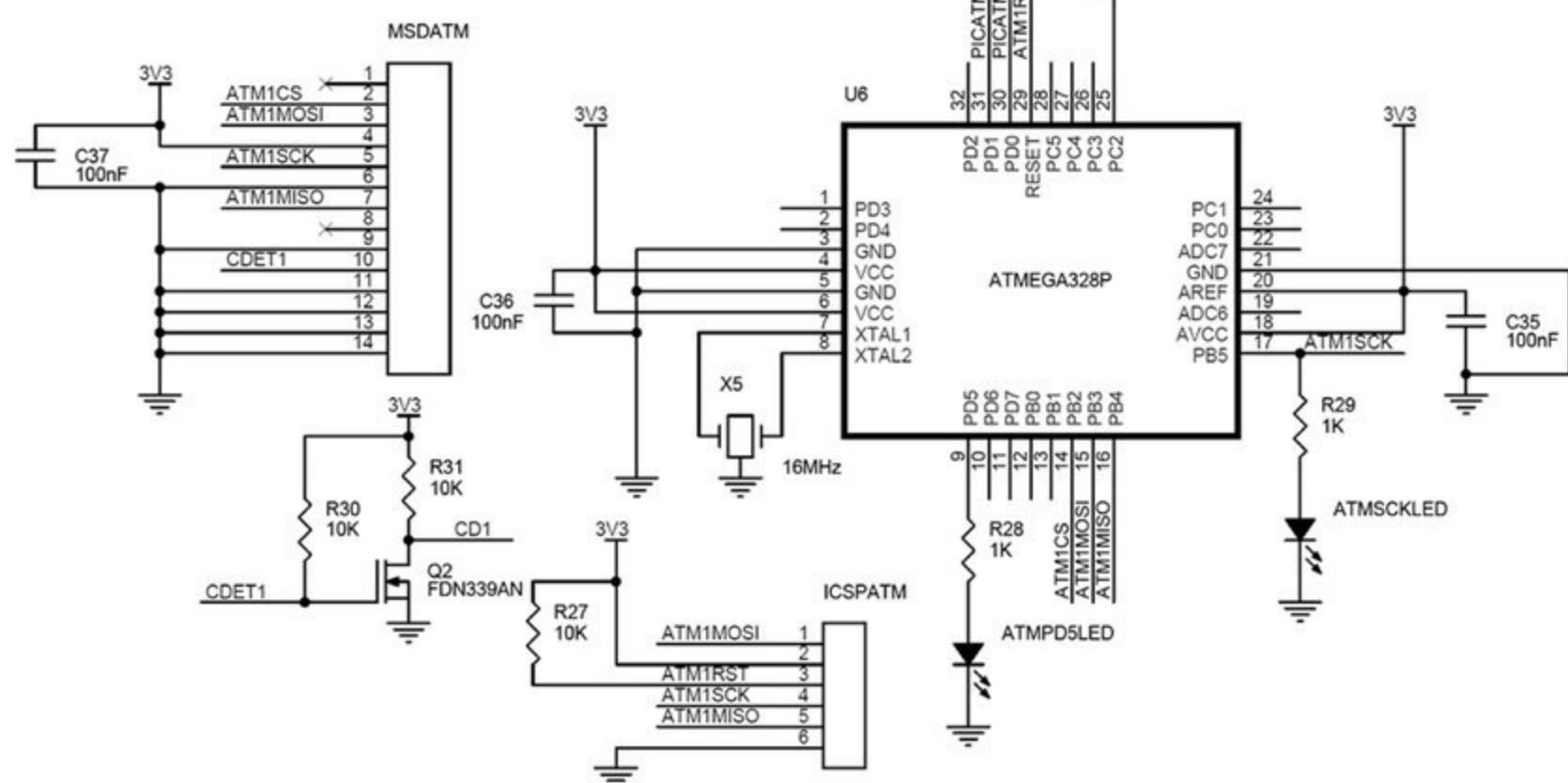
Despite all of the SPI portals, UARTs, clocks, and timers that the PIC32MX795F512L possesses, its most powerful asset is its Ethernet interface. As you can see in **Schematic 6**, the Ethernet circuitry isn't particularly complex. However, by including this circuitry, we instantly have the ability to contact other network-capable nodes on an LAN or over the Internet. Our board can suddenly become a TCP/IP server or client.

We can use the Ethernet portal to serve web pages. We can send email messages. We can synchronize with Internet time servers. If necessary, we can even bootload the PIC32MX795F512L over an Ethernet connection. The inclusion of the LAN8720A interface is well worth the loss of a few of the PIC32's I/O pins.

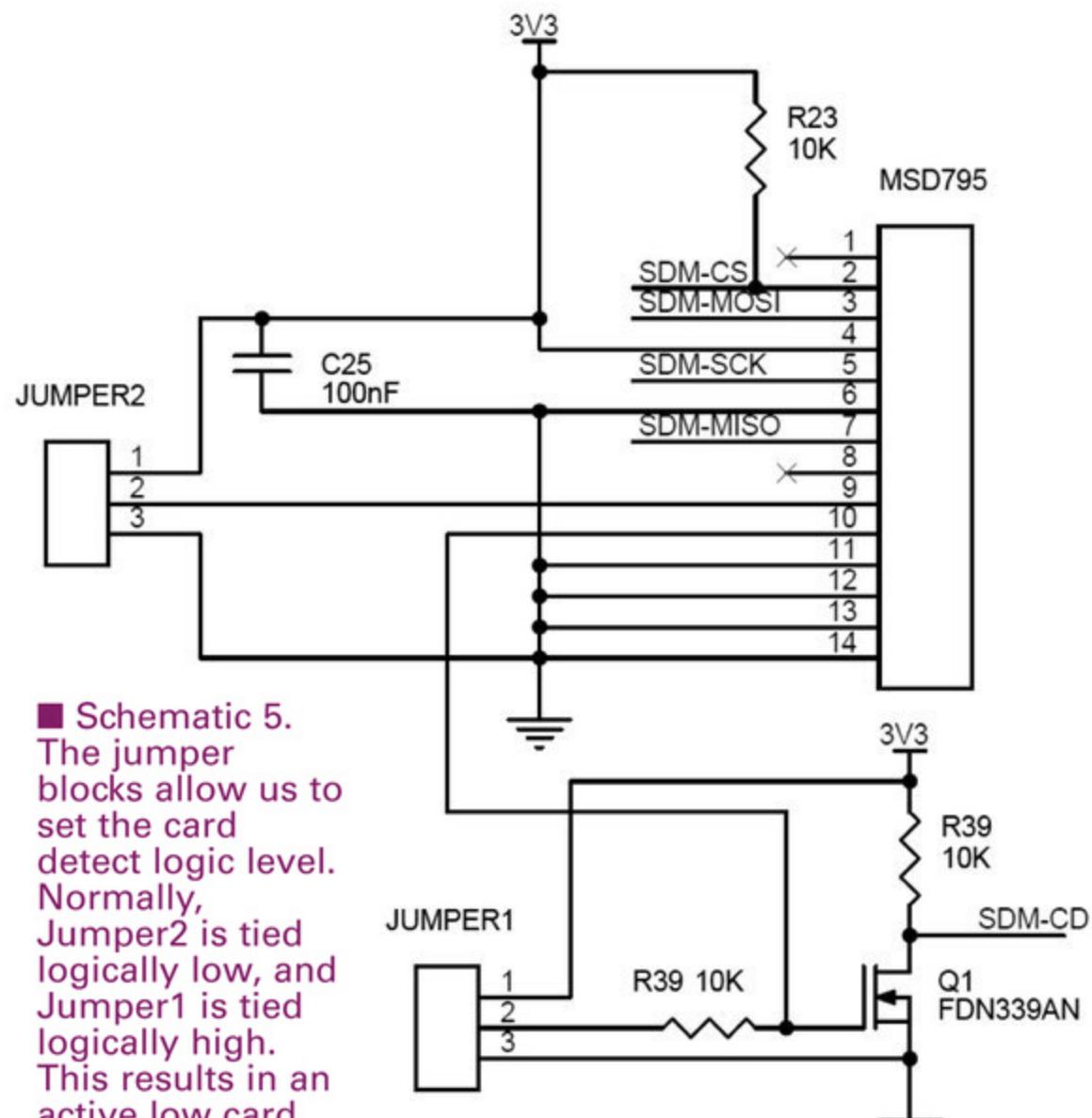
## Clean Power

No data will flow and no LEDs will blink if the power supply is inadequate. So, we must design in a robust and noise free power supply circuit. Fortunately, that spectrally clean power system consists of only three components.

If you include the optional power indicator LED and



■ Schematic 4. This is an implementation of the OpenLog, which can be purchased as a module from SparkFun. Any serial input is directed to the microSD card by the firmware contained within the ATmega328P microcontroller.

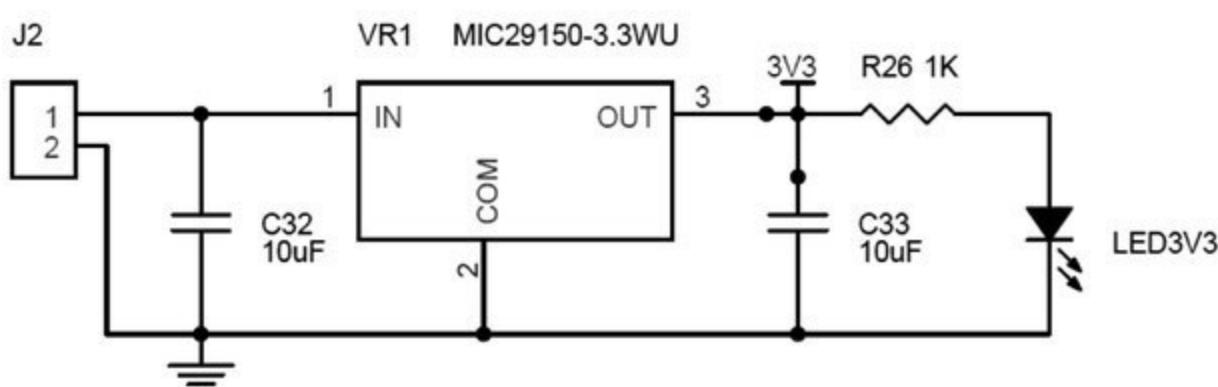
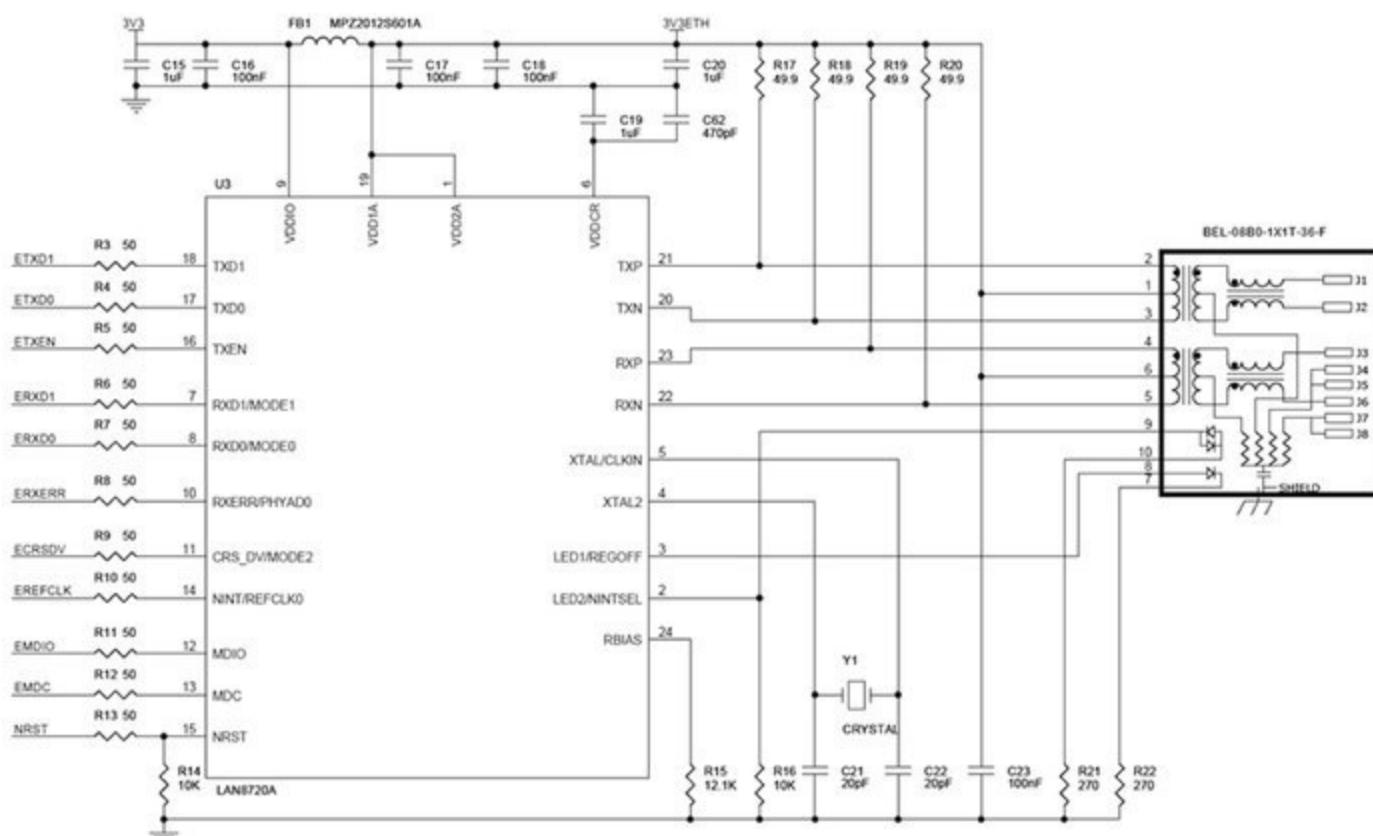


■ Schematic 5. The jumper blocks allow us to set the card detect logic level. Normally, Jumper2 is tied logically low, and Jumper1 is tied logically high. This results in an active low card detect signal.

its current-limiting resistor, the parts count rises to five components.

Wired Ethernet portals are typically power hungry. This design will draw around 250 mA while running the Microchip TCP/IP stack with all LEDs illuminated. The Micrel MIC29150 won't even break a sweat with that load. All five components plus the power jack make up **Schematic 7**.

■ Schematic 6. This is a classic implementation of the SMC LAN8720A. All of the signals needed to drive the external PHY are provided by the PIC32MX795F512L.



■ Schematic 7. As Leonardo da Vinci would say, "Simplicity is the ultimate sophistication." This is one simple rock-solid power regulator circuit.

## Shake Down

Let's power up and see if this thing works. We will test our new creation by loading and running the free Microchip TCP/IP stack. The first thing we need to do is make sure the PIC32MX795F512L's configuration fuses are set correctly:

```
#pragma config FPLLIDIV = DIV_1
#pragma config FPLLMUL = MUL_20
#pragma config FPLLODIV = DIV_2
#pragma config FWDTEN = OFF
#pragma config FPBDIV = DIV_1
#pragma config POSCMOD = XT
#pragma config FNOSC = PRIPLL
#pragma config CP = OFF
#pragma config FMIEN = OFF
#pragma config FETHIO = ON
```

As far as the fuses are concerned, we want to make sure we are running at 80 MHz. With an input frequency of 8 MHz, multiplied by 20 and divided by 2, we end up with 80 MHz.

We don't want the watchdog nipping at our heels, and the PIC32MX795F512L's configuration fuses reflect that the watchdog timer is indeed disabled. Along with the disabled watchdog timer, we don't want to code-protect

anything right now either.

Since we will be running the TCP/IP stack against the Ethernet interface, we want to make sure the PIC32MX795F512L's Ethernet signals are routed to the LAN8720A PHY correctly. That is done by making sure the *FMIEN* fuse is set to OFF and the *FETHIO* fuse is set to ON. This activates the normal set of the PIC32MX795F512L's Ethernet interface pins instead of its alternate set of Ethernet pins. If you examine **Schematics 1** and **6**, you will see that the alternate Ethernet signals are not tied to the LAN8720A.

The TCP/IP stack code we will run will have the web server (HTTP) module enabled. The TCP/IP stack HTTP server module includes provisions to control LEDs on the server hardware. We just happen to have a few LEDs on our board that we can put into service. The TCP/IP stack code calls out eight LEDs. We can map to five of them:

```
#define LED0_TRIS (TRISFbits.TRISF3) //ACT2
#define LED0_IO (LATFbits.LATF3)
#define LED1_TRIS (TRISAbits.TRISA3) //ACT1
#define LED1_IO (LATAbits.LATA3)
#define LED2_TRIS (TRISAbits.TRISA4)
//User1
#define LED2_IO (LATAbits.LATA4)
#define LED3_TRIS (TRISBbits.TRISB15)
//User2
#define LED3_IO (LATBbits.LATB15)
#define LED4_TRIS (TRISBbits.TRISB14)
//User3
#define LED4_IO (LATBbits.LATB14)
#define LED5_TRIS (TRISDbits.TRISD13)
//No such LED
#define LED5_IO (LATDbits.LATD13)
#define LED6_TRIS (TRISDbits.TRISD13)
//No such LED
#define LED6_IO (LATDbits.LATD13)
#define LED7_TRIS (TRISDbits.TRISD13)
//No such LED
#define LED7_IO (LATDbits.LATD13)
```

LEDs 5, 6, and 7 are mapped to the PIC32's D13 I/O pin, which is not used by our hardware. LED0 does double duty as the "I'm alive" blinker:

```
// Blink LED0 every second.
if(TickGet() - t >= TICK_SECOND/2ul)
{
    t = TickGet();
    LED0_IO ^= 1;
}
```

The *TICK\_SECOND* interval is determined by our peripheral clock speed, which we define via the configuration fuses. The TCP/IP stack gets at the speed values this way:

```
#define GetSystemClock() (80000000ul)
```

```
#define GetInstructionClock()
    (GetSystemClock() / 1)
#define GetPeripheralClock()
    (GetSystemClock() / 1)
```

In addition to the TCP/IP stack's *TICK\_SECOND* interval, the PIC32MX795F512L's UARTs and SPI portals derive their baud rates from these speed values.

While we're at it, let's map in that single pushbutton switch:

```
#define BUTTON0_TRIS  (TRISGbits.TRISG32)
    //SW2
#define BUTTON0_IO    (PORTGbits.RG2)
#define BUTTON1_TRIS  (TRISDbits.TRISD13)
    //No Button
#define BUTTON1_IO    (PORTDbits.RD7)
#define BUTTON2_TRIS  (TRISDbits.TRISD13)
    //No Button
#define BUTTON2_IO    (PORTDbits.RD13)
#define BUTTON3_TRIS  (TRISDbits.TRISD13)
    //No Button
#define BUTTON3_IO    (PORTDbits.RD13)
```

In addition to controlling our board's LEDs, the TCP/IP stack also contains code that senses the pushbutton status.

We can test our Ethernet portal, the LEDs, and the pushbutton switch by simply running the HTTP server module of the TCP/IP stack. The default Microchip web page that is served contains visual LED and pushbutton switch indicators. The LEDs can be illuminated and extinguished via a click of the mouse. The pushbutton status reflects the state of the pushbutton on our board.

In that we are depending on a served web page to confirm our hardware, it would be nice to define the 25LC1024 hookup. The 25LC1024 is responsible for housing the web page binary image. Here's what the TCP/IP stack wants to see:

```
#define EEPROM_CS_TRIS      (TRISAbits.TRISA15)
#define EEPROM_CS_IO          (LATAbits.LATA15)
#define EEPROM_SCK_TRIS      (TRISDbits.TRISD10)
#define EEPROM_SDI_TRIS      (TRISCbits.TRISC4)
#define EEPROM_SDO_TRIS      (TRISDbits.TRISD0)
#define EEPROM_SPI_IF         (IFS0bits.SPI1IF)
#define EEPROM_SSPBUF         (SPI1BUF)
#define EEPROM_SPICON1        (SPI1CON)
#define EEPROM_SPICON1bits   (SPI1CONbits)
#define EEPROM_SPICON2        (SPI1CON2)
#define EEPROM_SPISTAT        (SPI1STAT)
#define EEPROM_SPISTATbits   (SPI1STATbits)
#define EEPROM_SPIBRG         (SPI1BRG)
```

That should be enough to get us started. So, let's feed the MIC29150 +5 VDC and see what happens.

## nemo.dyndns-server.com

That happens to be the URL that calls up the web page from our PIC32MX795F512L that is currently running the TCP/IP stack. I placed *nemo.dyndns-server.com* in the host list of my DYN account. My DYN



TCP/IP Stack Demo Application

Overview
Dynamic Variables
Form Processing
Authentication
Cookies
File Uploads
Image Uploads
Send E-mail
Dynamic DNS
Network Configuration
SNMP Configuration

## Welcome!

Stack Version: v5.42

Build Date: Jun 18 2015 00:08:00

This site demonstrates the power, flexibility, and scalability of an 8, 16, or 32-bit embedded web server. Everything you see is powered by a Microchip PIC microcontroller running the Microchip TCP/IP Stack.

On the right you'll see the current status of the demo board. For a quick example, click the LEDs to toggle the lights on the board. Press the push buttons (except MCLR!) or turn the potentiometer and you'll see the status update immediately. This examples uses AJAX techniques to provide real-time feedback.

This site is provided as a tutorial for the various features of the HTTP web server, including:

- **Dynamic Variable Substitution** - display real-time data
- **Form Processing** - handle input from the client
- **Authentication** - require a user name and password
- **Cookies** - store session state information for richer applications
- **File Uploads** - parse files for configuration settings and more

■ **Screenshot 1.** I went around the horn to get to our board's Ethernet interface. The URL [nemo.dyndns-server.com](http://nemo.dyndns-server.com) maps back to the Cisco router on my bench. Our board is programmed to sit at 192.168.0.99 on the EDTP LAN.

account tracks the IP address of the Cisco router that is running on my bench, so I can access my router from the Internet by simply using *nemo.dyndns-server.com* as the target URL. Since our board is physically attached to the shop's LAN, I could have also entered 192.168.0.99. Here is the TCP/IP stack information that makes that possible:

```
#define MY_DEFAULT_MAC_BYTE1      (0x00)
#define MY_DEFAULT_MAC_BYTE2      (0x04)
#define MY_DEFAULT_MAC_BYTE3      (0xA3)
#define MY_DEFAULT_MAC_BYTE4      (0x00)
#define MY_DEFAULT_MAC_BYTE5      (0x00)
#define MY_DEFAULT_MAC_BYTE6      (0x00)

#define MY_DEFAULT_IP_ADDR_BYTE1  (192ul)
#define MY_DEFAULT_IP_ADDR_BYTE2  (168ul)
#define MY_DEFAULT_IP_ADDR_BYTE3  (0ul)
#define MY_DEFAULT_IP_ADDR_BYTE4  (99ul)
```

Either way, we get our web page which is captured in **Screenshot 1.**

## It Works!!

However, we still have more firmware work to do. We still need to verify the pair of microSD subsystems and the remaining UART interfaces.

For now, the LEDs on our PIC32MX795F512L board follow the clicks of the mouse on the web page LED indicators, and the pushbutton switch toggles the web page's buttons indicator. The "I'm alive" LED is also working as designed.

In the next installment of Design Cycle, we will focus on completing the firmware that brings our PIC32MX795F512L board's silicon to life. **NV**

LEDs:	(click to toggle)
Buttons:	V V V A
Potentiometer:	14

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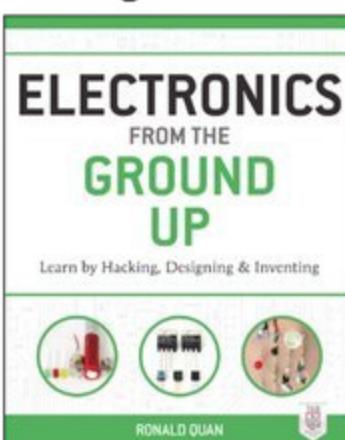
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Ronald Quan

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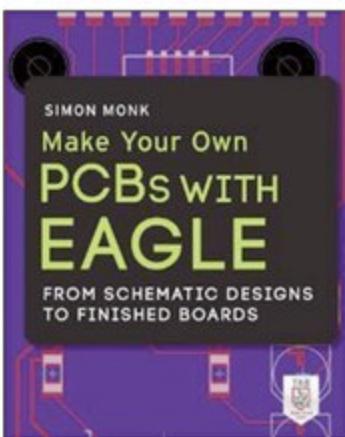
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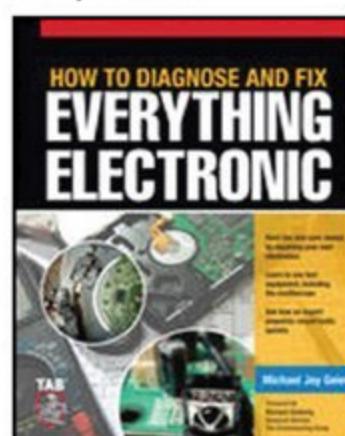


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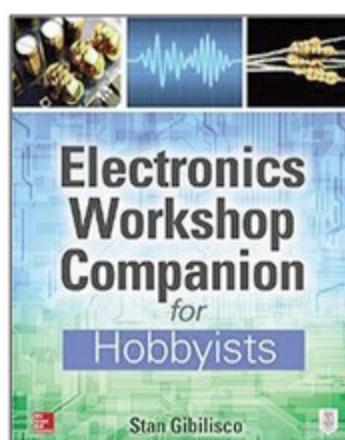
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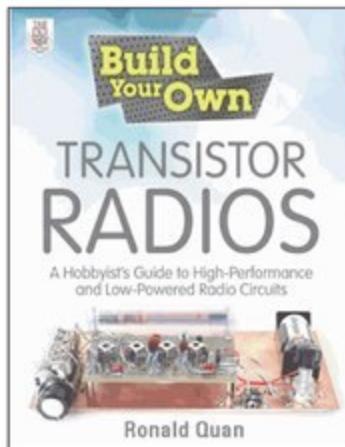


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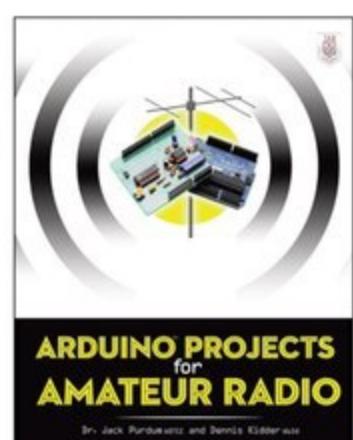
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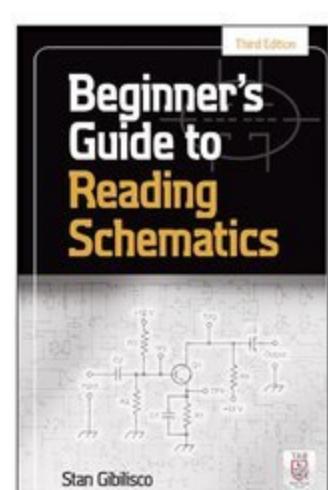
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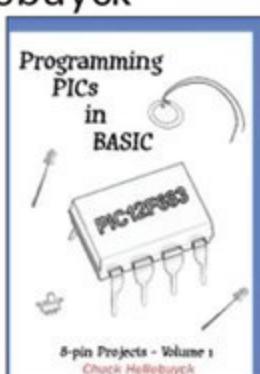
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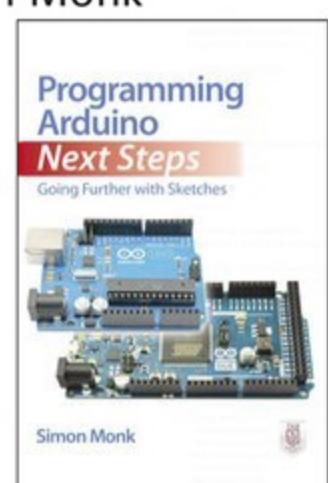
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### Wireless Freezer Alarm



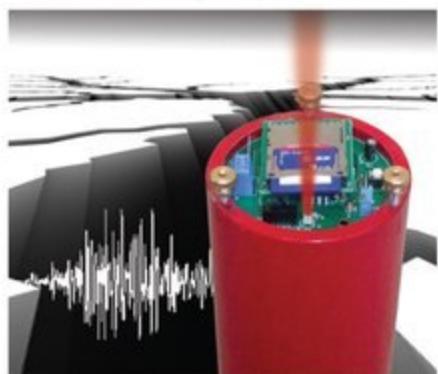
Looking for a way to protect all your frozen yummies??? In the June 2015 issue we have an article that will help you do just that.

The kit includes:

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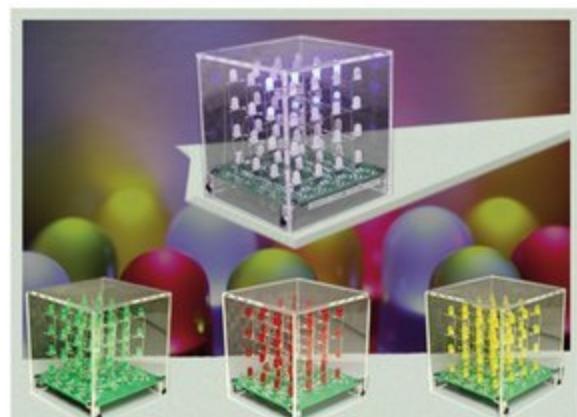


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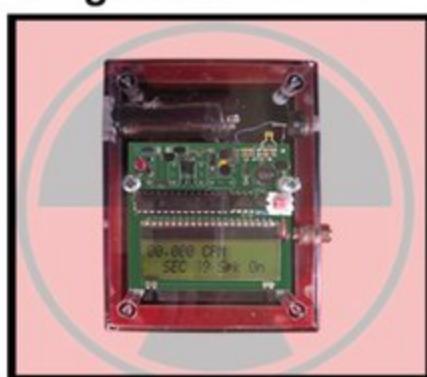
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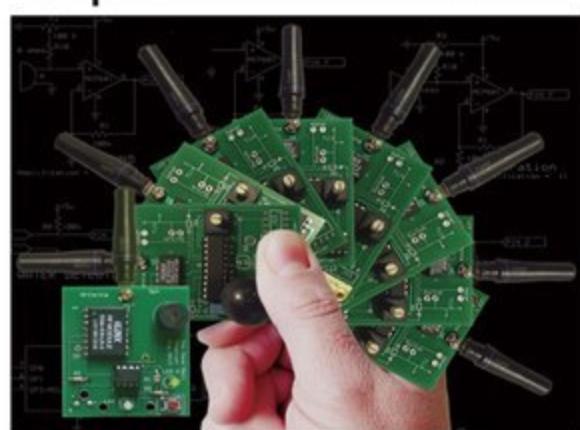


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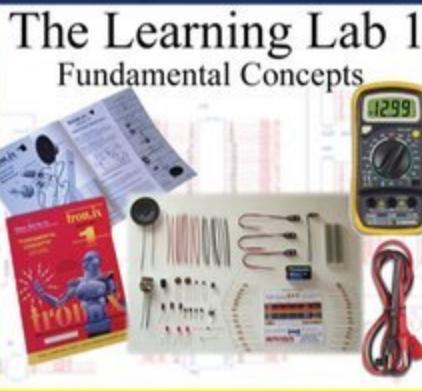
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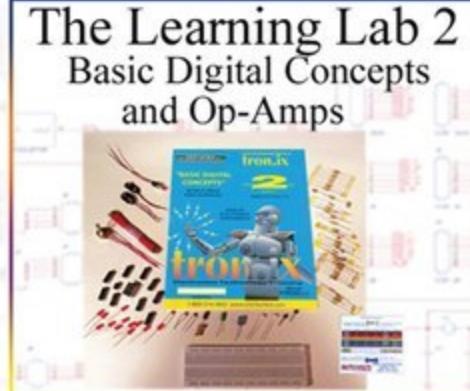


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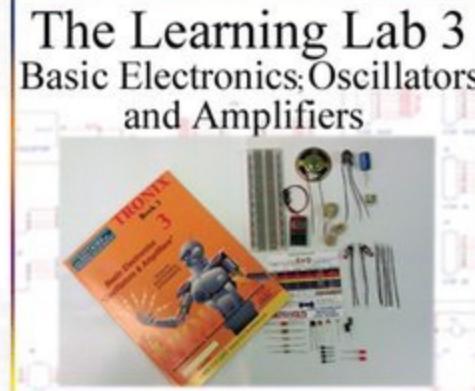
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## ■ NEW PRODUCTS

Continued from page 21

currents even in tight spaces, clamping onto conductors up to 5 mm in diameter.

Many current probes require external power supplies or amplifiers to display a waveform on an oscilloscope screen, but the CP030A and CP031A probes connect directly to Teledyne LeCroy's oscilloscopes through a built-in front panel ProBus interface, thus requiring no additional external hardware. This connection allows communication between the current probe and the scope, resulting in current waveforms that are automatically displayed on screen in amps and calculated power traces scaled correctly in watts. This full integration also allows for degauss and autozero functions to be accomplished directly from the oscilloscope's user interface. Teledyne LeCroy current probes are available in a variety of models for a wide range of applications; prices start at \$3,790. The full range of current probes includes models with bandwidths up to 100 MHz, peak currents up to 700A, and sensitivities to 1 mA/div. Teledyne LeCroy current probes are often used in applications such as the design and testing of switching power supplies, motor drives, electric vehicles, and uninterruptible power supplies.

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## BGA SOCKET FOR TESTING DEVICES WITH SMART FEATURES

Ironwood Electronics recently introduced a new BGA socket that addresses high performance requirements for testing BGA devices with smart features. The contactor is a stamped spring pin with 17 gram actuation force per

Continued on page 75

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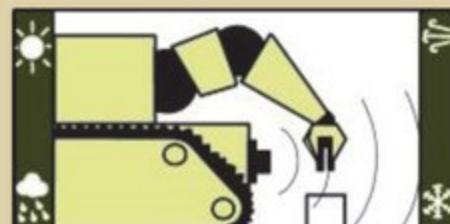
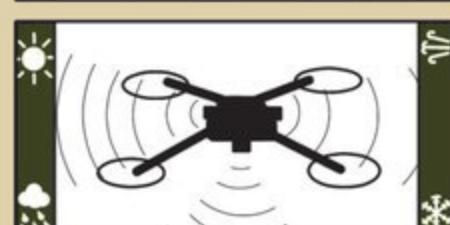
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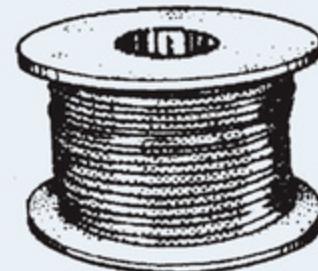
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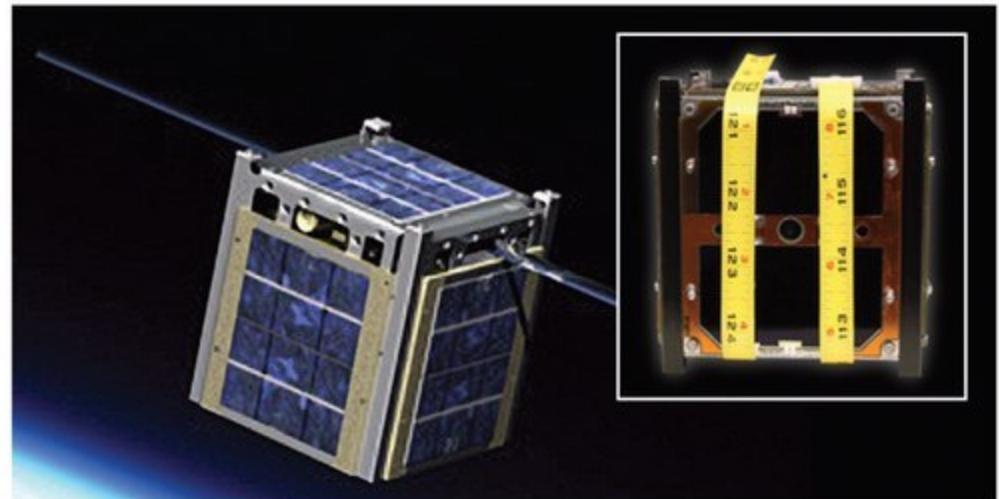
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# CubeSats — Part 5: Designing a Model CubeSat for High School Use

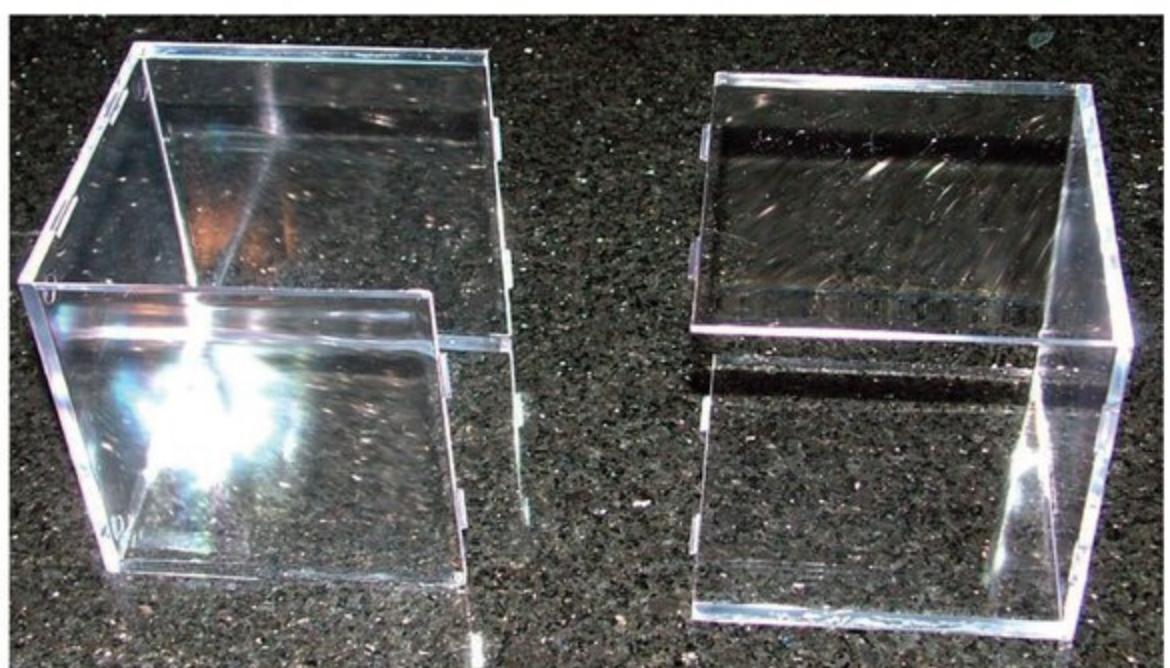
As CubeSats continue to play a pivotal role in space exploration, it's important to introduce more schools to their technology. There are CubeSat teaching kits on the market to meet this need; however, I want to see one that primary and secondary schools can afford. Besides, I strongly believe that space and near space make excellent STEM platforms, and a model CubeSat could tap into middle and high school student's interests. Therefore, this month I'll describe a CubeSat kit I'm designing with the intent of using it in my high school.



Sure, my Model CubeSat is not the real thing, but it is close enough for elementary and secondary classrooms. *Real CubeSat image courtesy of the Jet Propulsion Laboratory.*

## The Affordable CubeSat Airframe

First things first, this is not a real CubeSat kit; that is, you can't launch the finished product into space. For one thing, the body is plastic and outgases in the vacuum of space. Second, the bus does not meet the PC104 standard. Aside from these issues, however, it's a pretty decent model that I believe will become an



A baseball display is perfectly square and as a result, it's difficult to identify which two sides slide apart.

## APPROACHING THE FINAL FRONTIER

Post comments on this article and find any associated files and/or downloads at [www.nutsvolts.com/index.php?/magazine/article/august2015\\_NearSpace](http://www.nutsvolts.com/index.php?/magazine/article/august2015_NearSpace).

exciting satellite kit that will help motivate America's next generation of aerospace engineers.

The concept of stacking PCBs (printed circuit boards) to form the layers of a CubeSat was pretty simple to grasp. Therefore, the issue I actually struggled with the most was the airframe of the CubeSat. I was flummoxed to come up with a simple and inexpensive solution, and was at the point of asking a friend to laser-cut sheets of acrylic plastic. Using laser-cut panels would raise the cost of the Model CubeSat kit, so I was hesitant to go this route. Then, one afternoon the solution found me.

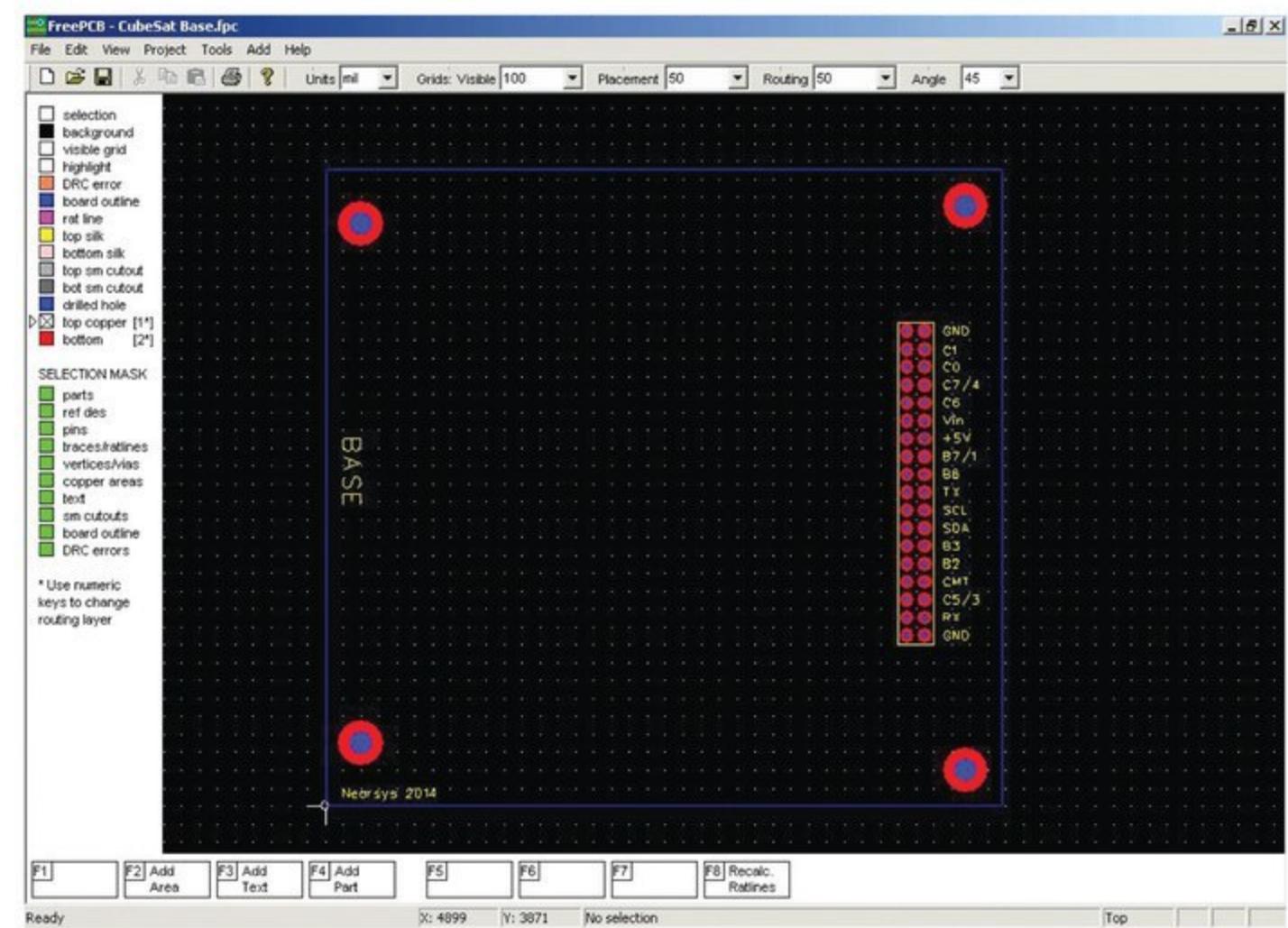
I occasionally visit the Interstate Plastic store in Boise, ID to look over their scraps for ideas. One day while rummaging through their scrap pile, I found a discounted item: a plastic display cube for baseballs.

The cube slides open into two pieces, with each piece being a "C" shaped sheet of plastic. The sturdy walls of the baseball display are 1/8" thick, and it's a perfectly square cube that measured 4-3/32" across. That's close enough for a CubeSat model, and I'd be able to stack my fake PC104 cards inside of it.

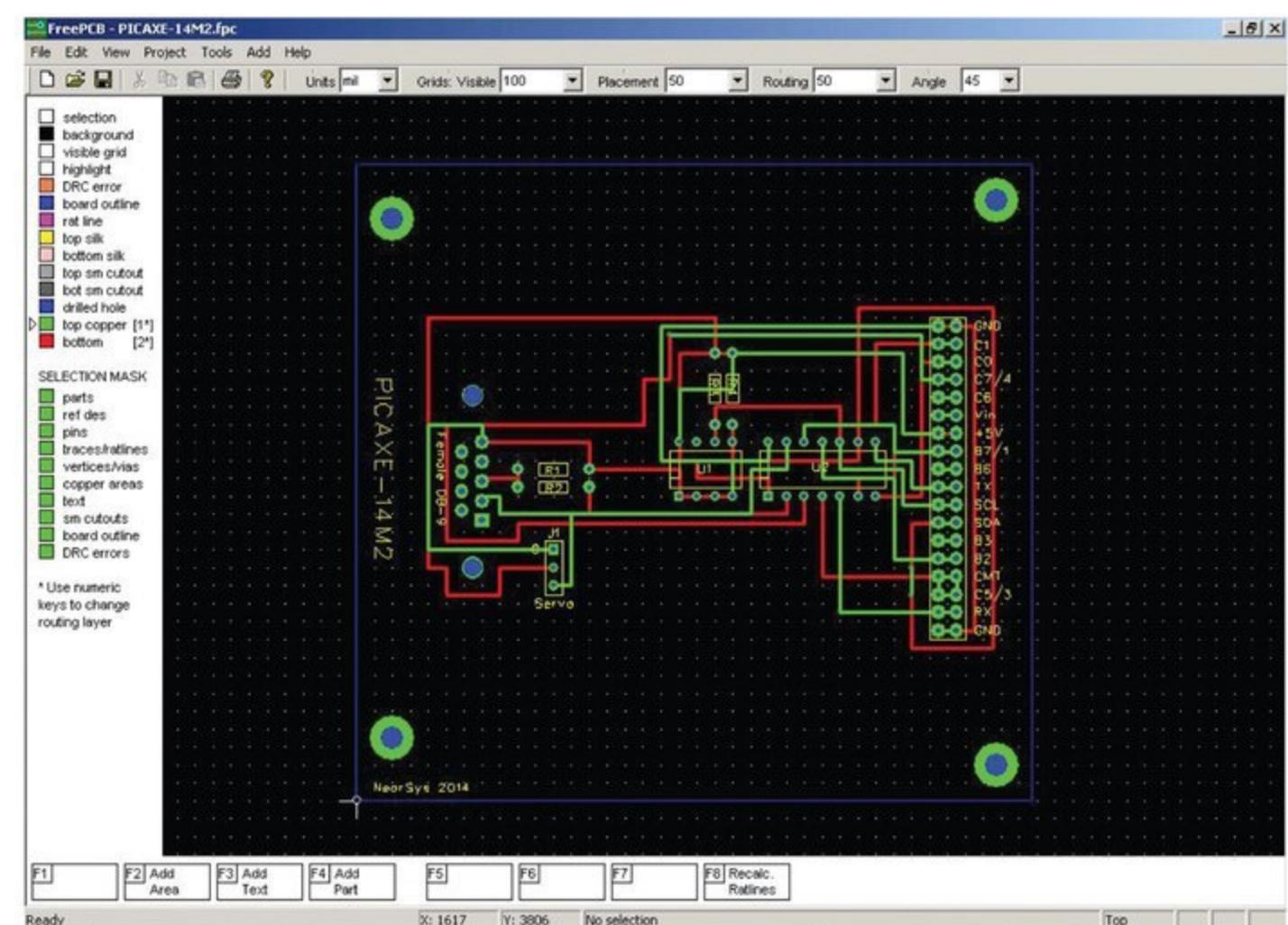
## Making Printed Circuit Cards

Now that I had a cube, it was time to make printed circuit boards for the electronics. Before I could design PCBs for the CubeSat, I needed to select a microcontroller and design its bus. A real PC104 card supports pretty sophisticated microcontrollers and single-board computers (SBCs), and uses a 104-pin bus. I had no intention of doing the same because I was creating a CubeSat kit for a PICAXE microcontroller.

A PICAXE-14M2 or 18M2 would suit the purposes of the kit since they were programmed in BASIC. Using BASIC meant the Model CubeSat would have a shallower learning



By modifying the Model CubeSat's generic plane, I can create new planes with novel features that are guaranteed to stack with the rest of the CubeSat planes.

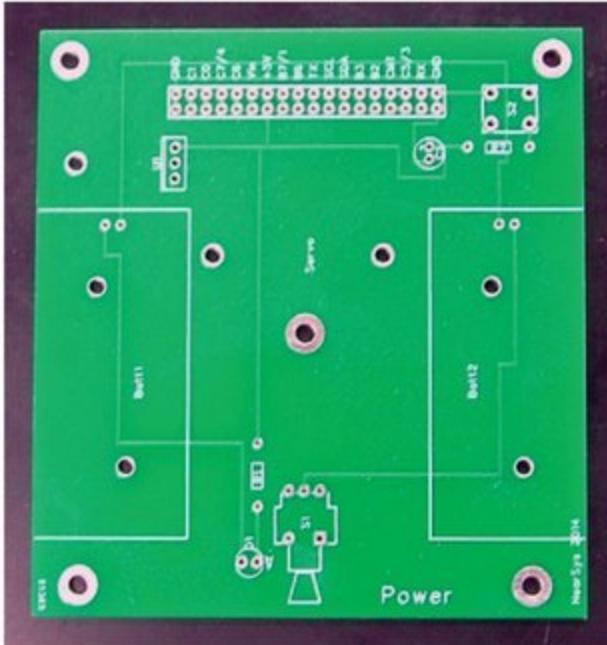


For this microcontroller plane, I started out with the generic plane and added the components for supporting a PICAXE-14M2 and I<sup>2</sup>C memory.

curve than would using something like C#. Since the microcontroller would be a PICAXE, I decided to use an 18-pin bus contained on a 2 x 18

pin SIP (two rows of the same pins) for stability and strength.

Below are the pin functions of the bus. If the PICAXE-14M2 is used,



The Model CubeSat kit contains a series of PCBs like this one. Instructions included in the kit — along with the top silk on each PCB — will explain the proper placement of the electronic components.

then not all of the pins in the bus are available.

- GND (Ground)
- C.2 (I/O)
- Commit (Input only)
- Commit (Input only)
- B.2 (I/O)
- B.3 (I/O)
- SDA (I<sup>2</sup>C)
- SCL (I<sup>2</sup>C)
- B.5 (I/O)
- B.6 (I/O)
- B.7 (I/O)
- +5V (Regulated five volts)
- Vin (Input voltage)
- C.6 (I/O)
- C.7 (I/O)
- C.0 (I/O)
- C.1 (I/O)
- GND (Ground)

Each plane was created on FreePCB, and based on a generic plane I initially created. Opening the generic plane and then modifying it for a new one ensures that the new plane fits the other existing planes.

Each plane has the dimensions of a PC104 card, and has a minimum of the 2 x 18 pin SIP and four 1/4" diameter holes in the corners. When stacked together with the SIP and spacers, each plane is 5/8" apart.



The current radio used in the Model CubeSat doesn't need an antenna. So, the "antenna" is just bolted to the top of the CubeSat's plastic frame. In the future, I plan to connect the antenna to the radio.

That way, an amateur rocket can launch the Model CubeSat several thousand feet into the air where a ground station can communicate with it during its descent.

## The Planes (So Far)

To date, I am happy with four planes that I've created. There is more work to do with regard to tweaking older planes and building new versions. For one, I found the Model CubeSat could use all the I/O on the bus, so I will need to focus more attention on the PICAXE-18M2 version of the control plane.

Currently, I'm experimenting with the following planes as I write this article: power; microcontroller; photometer; and radio.

## Power Plane

The initial version of the power plane uses four "AAA" cells, but will eventually contain a rechargeable lithium polymer battery. That's because I find it's too much trouble to destack the CubeSat when the batteries are dead.

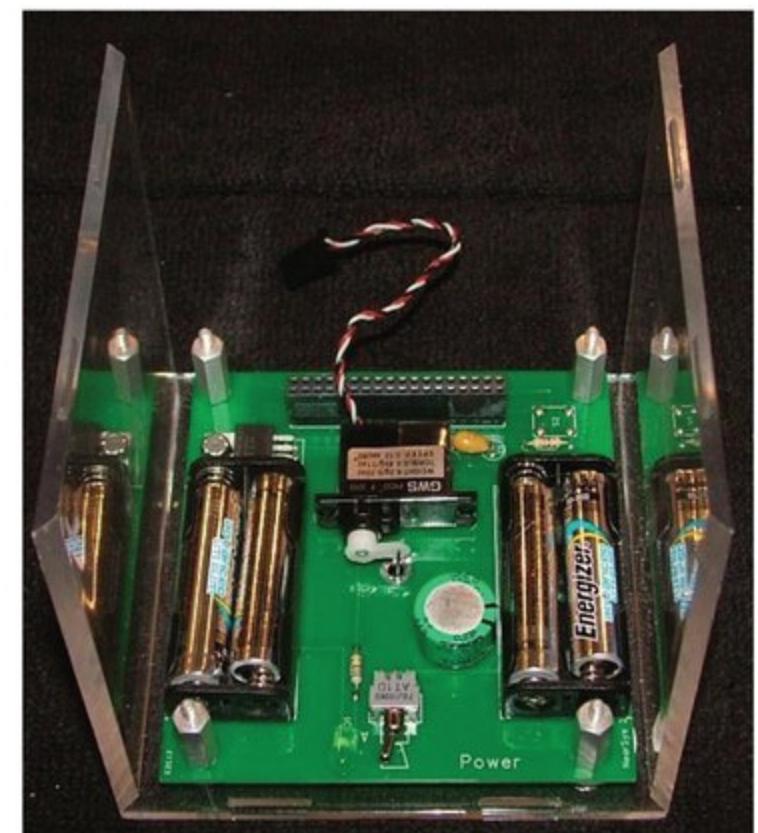
Real CubeSats use hot wire cutters to release deployables like antenna elements and solar panels. That's too hazardous for students, so instead, the power plane (which is always located at the bottom of the stack) contains a micro-servo that lifts a pin to release CubeSat deployables.

For now, I've bolted a length of metal tape measure to the top of the

CubeSat's airframe to act as its deployable antenna. Attached to the ends of the metal tape are loops of Dacron string that reach the metal pin attached to the micro-servo's horn. When the servo rotates up, it lifts the pin and releases the antenna elements. The antenna then snaps out with a pop that will startle you if you aren't prepared.

Soldered to the underside of the power plane is a momentary tactile switch.

This replicates the switch CubeSats use to detect that they've



The power plane with its battery holders, switch, and antenna-release servo.

been released from their P-POD dispenser.

The current program in the Model CubeSat waits in a loop for a button to be pressed before beginning its mission and releasing the antenna. Eventually, I'll find a tactile switch with a longer pushbutton that actually protrudes from the bottom of the airframe. The Model CubeSat will wait until it's lifted off the table to signal it's been dispensed from its P-POD. One other thing I discovered about the power plane is that the main power switch must be replaced; it's too difficult to reach inside the airframe and flip on the switch it's currently using. I'll replace it with a pushbutton switch with a plunger long enough to reach the surface of the airframe.

## Microcontroller Plane

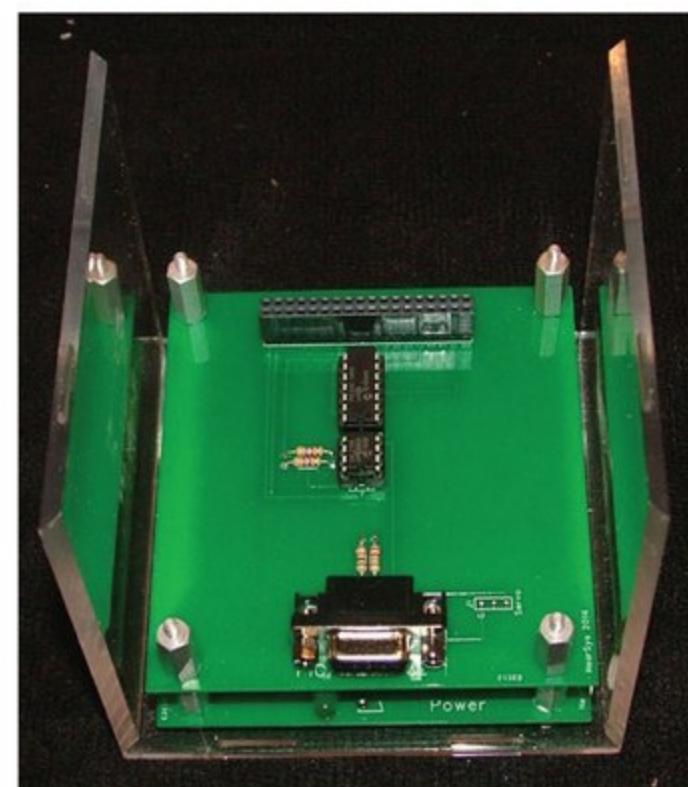
The microcontroller plane supports the PICAXE and I<sup>2</sup>C memory chip. The memory allows the Model CubeSat to store science data until its next radio contact with the ground station. There are two changes I want to make, however.

First is to shift the DB-9 programming header outward just a bit more. Right now, it's just beyond reach of the PC's programming cable. Then, on the underside of the PCB, is a right angle header for the deployables' micro-servo. I want to move that servo header to the power plane in the next version.

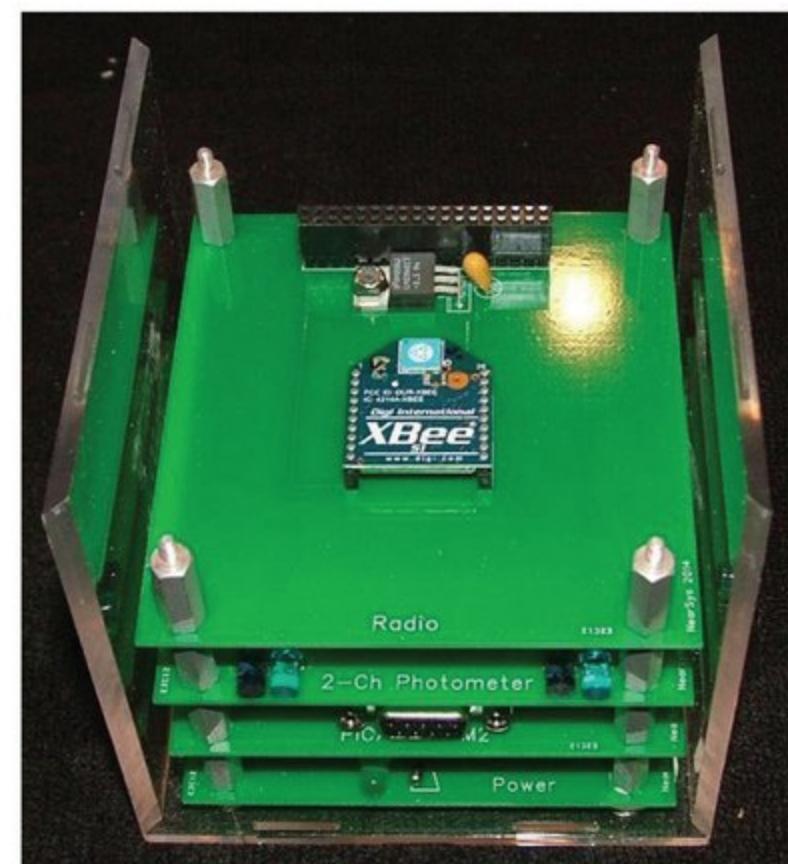
## Photometer Plane

Currently, the only science-related plane for the Model CubeSat is a two-channel LED photometer. This measures light intensity in the blue and infrared portions of the spectrum. A future upgrade will let students select which two colors of the spectrum to measure.

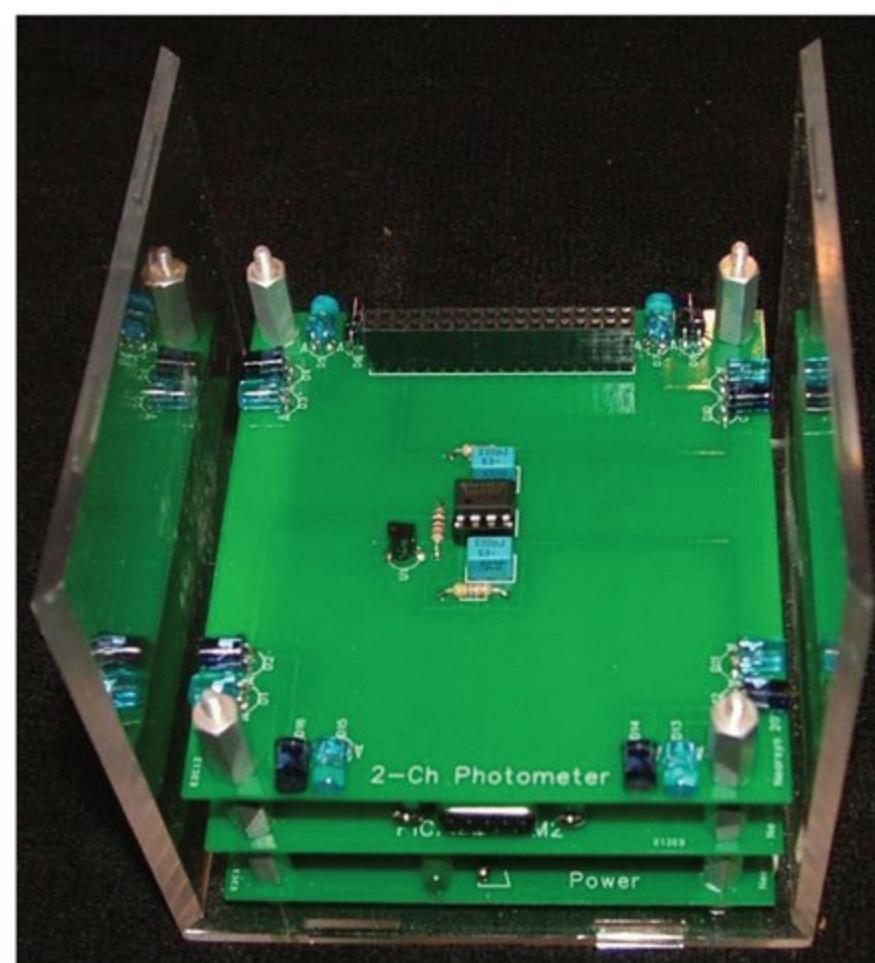
There are LED detectors at each corner of the PCB in the hopes that



This microcontroller plane contains a PICAXE-14M2. Eventually, I'll switch to a PICAXE-18M2 for access to more I/O.



The XBee radio provides two-way communication between the Model CubeSat and the ground station.



The first science-focused plane is the photometer plane.



Something borrowed, something blue. This XBee radio is from a moon rover project I made using CheapBots.

## Radio Plane

The last plane is the radio plane. It provides two-way communication with a simulated ground station. The radio is an XBee radio and the plane converts the main +5V power supply to +3.3V for the radio (the +3.3 volts is limited to just the plane and not available over the bus). Communication is serial and uses the TX and RX pins in the Model CubeSat's bus.

So, what about the ground station? The ground station I'm using was originally designed for a moon

using many LEDs will make the CubeSat less sensitive to pointing direction. The plane also contains an LM335 temperature sensor to calibrate the LED's output (LEDs are sensitive to their temperature). The photometer's intensity readings appear on a bus I/O as a variable voltage where they are then digitized by the microcontroller.

rover robot project I built five years ago. It uses a PICAXE-08M2 to interface a PC to its XBee radio.

Communication with the PC is through the Terminal program included in the PICAXE Program Editor. This means the ground station's PICAXE coordinates and formats communicate between the radio and PC so that an operator can easily understand what information the Model CubeSat is telemetering.

## What's Next?

The Model CubeSat is still a work in progress. In the near term, however, I want to develop the following additions.

First, the Model CubeSat needs more I/O in order to take advantage of its volume. I've already designed the PCB for a PICAXE-18M2 microcontroller plane; I just need to design additional PCBs before I can send it out for manufacture (I prefer to combine several different PCBs and then panelize them in order to save money).

Second, the Model CubeSat needs a communications protocol. I designed one for my moon rover and plan to use a variation of it for the Model CubeSat. That would allow the CubeSat to store and download data like real

CubeSats do when they're out of range of a ground station.

I want additional science and engineering planes. That way, the Model CubeSat can be restacked and reconfigured for new missions. The latest plane I've designed is a sun sensor and magnetometer plane. It detects which surface of the CubeSat faces the Sun and the orientation of Earth's magnetic field relative to the CubeSat. This will permit the Model CubeSat to determine its attitude in space.

Another plane I'd like to create is a Geiger counter plane to allow the CubeSat to determine the amount of radiation around it.

What does a CubeSat do with attitude information? Aside from transmitting that information to the ground station, it can be used to help hold the attitude of the CubeSat with magnetorquers. That's not really practical with this model, but I will create a plane to simulate magnetorquers.

In place of magnetorquers will be bi-colored LEDs that illuminate when the magnetorquers are energized. So, when the Model CubeSat is out of its desired orientation, the LEDs turn on indicating the magnetorquers are active. The color of the LEDs will indicate the polarity of the magnetorquers. Then, when the Model CubeSat is turned back to its desired attitude, the LEDs are turned off.

A more difficult addition, I think, is using real solar panels to recharge the CubeSat's battery. The solar panels would measure 4" square and would need to be encapsulated for durability. The panels would mechanically attach to the Model CubeSat airframe and electrically connect to their own plane. The solar panel's current would then feed into the Vin pin of the Model CubeSat bus. The recharging circuit would need to be an upgraded power plane.

Finally, I want to add a camera. A slow scan camera would be ideal, but even a baby monitoring camera would be fine. The Model CubeSat would activate the camera when commanded to do so by the ground station. I'm assuming I'll use different transmitters and frequencies for the camera and XBee. Therefore, while the camera is transmitting an image, there would be no further communication over the XBee in order to simulate the CubeSat using the same radio for both functions.

When I think about it, I guess I'm only half way done with just the design of the Model CubeSat. There's still a lot of work developing new planes, writing code, and writing directions for students. However, it's my hope to make this kit available to schools as a complete curriculum that teaches electronics, programming, and engineering. With space as its focus, I think many students will find it a motivating project to work on.

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## ■ NEW PRODUCTS

Continued from page 69



ball, and a cycle life of 500,000 insertions. The self inductance of the contactor is 0.98 nH, insertion loss < 1 dB at 21.9 GHz. The current capacity of each contactor is four amps at 30°C temperature rise. Socket temperature range is -55°C to +180°C.

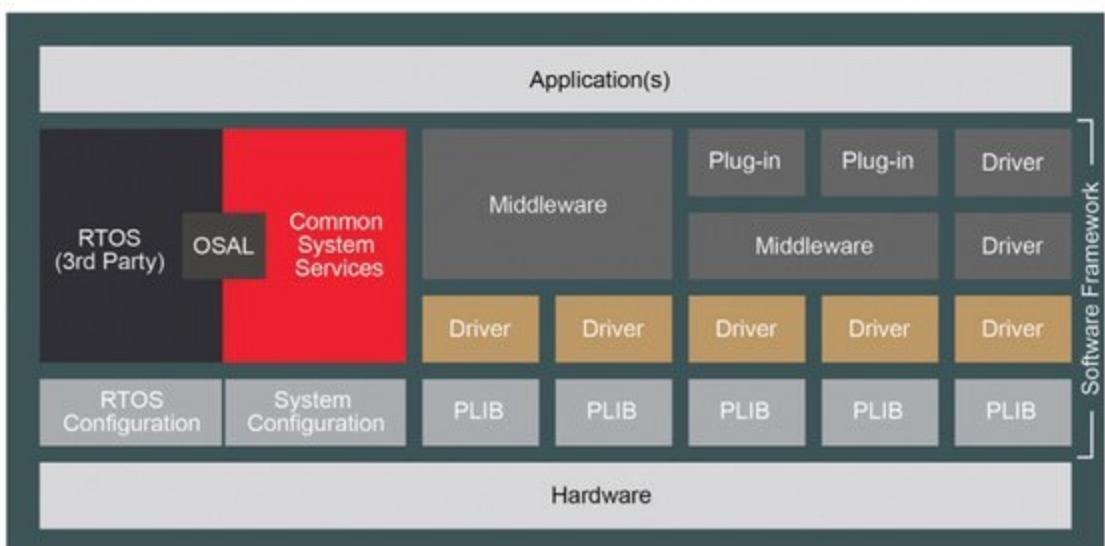
The socket also features a floating guide for precise ball to pin alignment and a Bluetooth electronic module integrated into the top portion of the socket (compression plate). A thermo couple sensor is brought down from the electronic circuitry to the internal socket cavity where the BGA is placed. When the BGA is placed and compressed against a printed circuit board (PCB) via the contact element, the thermo couple touches the top BGA surface.

Power is applied to the BGA to start its function. As the BGA starts functioning, heat is generated. This heat is sensed by the thermocouple and fed to the electronic circuitry where it is processed, then the temperature is displayed via a Bluetooth mobile app. The app monitors temperature continuously and provides results in graphical format. This feature is very useful for testing during BGA characterization. All BGA sockets can be integrated with this smart feature depending on space availability. Custom features can be added to any of the company's standard BGA sockets, as well. Contact Ironwood Electronics for a price quote.

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## PIC32 HARMONY SOFTWARE DECODER FRAMEWORK

**M**icrochip Technology, Inc., now has available the PIC32 Harmony Software Decoder Framework and Microsoft Windows Media Audio (WMA) Decoder Library



for 32-bit PIC32 microcontroller (MCU)-based consumer-audio application development within the MPLAB® Harmony Integrated Software Framework. The WMA Decoder Library includes a new modular framework for audio decoders including support for MP3 and AAC, allowing for easier audio application development.

Microchip's Audio Decoder Framework allows for audio software codecs to be easily added to a PIC32 design project. Rather than having to rewrite large sections of application code, the framework allows for easier integration into an existing customer application after the corresponding decoder library has been purchased. The WMA Decoder increases the depth of the library for PIC32 MCU-supported audio decoders, in addition to MP3 and AAC. This increases the range of audio formats that designers can choose to support.

The audio decoder framework within the Harmony environment allows designers to easily add, subtract, and switch among various software-based audio decoders. Additionally, including a WMA decoder gives developers an even wider set of options and support for audio playback.

The WMA Decoder Library is targeted for low cost applications in consumer markets such as audio docks, home audio receivers, and automotive head units. It gives developers added flexibility in decoder options that play back from internal or removable media. The addition of a WMA Decoder Library further expands the audio application flexibility of PIC32-based designs, building upon existing USB and Bluetooth streaming audio solutions.

The Microsoft WMA Decoder Library (part #s SW320015 and SW320025-1HPM, \$199.97 and \$199.00) is supported by Microchip's free MPLAB Harmony Integrated Software Framework and PIC32 Bluetooth Audio Development Kit (part # V320032, \$199.99), all of which are available now.

For more information, contact:  
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# Pegboard Solder Holder

I am constantly looking for my roll of solder. I like to use a water-soluble flux version so I can wash off the solder flux with water and a toothbrush. The result is a professional looking solder joint. Because of this, I'm very specific about what solder I use for projects around my lab and end up often moving the solder roll. I also oftentimes forget where I put it, or it ends up under a pile of tools or circuit boards. So, having a dedicated place to put my solder would be handy, and what better place than hanging it from the pegboard at the back of my bench. A custom 3D printed solder holder was an easy solution to give the solder roll a place of its own.

I launched the free-to-use Tinkercad software from my Chrome browser (which is recommended) and began the design. It really didn't take a lot of time to create the actual piece, but getting the spacing right was the toughest part. I decided to just use a screw and nut to secure the holder to the pegboard. I didn't trust a plastic hook to hold up. I also wanted a couple of guide pins to locate the bracket and eliminate the need for two screws.

I wanted some strength, so I used a triangle support bracket from the base up to the post that will hold the solder roll. **Figure 1** shows the completed design.

The design consisted of multiple objects essentially glued together to make the final piece. I like Tinkercad because it makes 3D design as easy as building with blocks like I did as a kid. In places where I need to take material away, I just create an object that is a "hole" and that removes anything it touches rather than add to it.

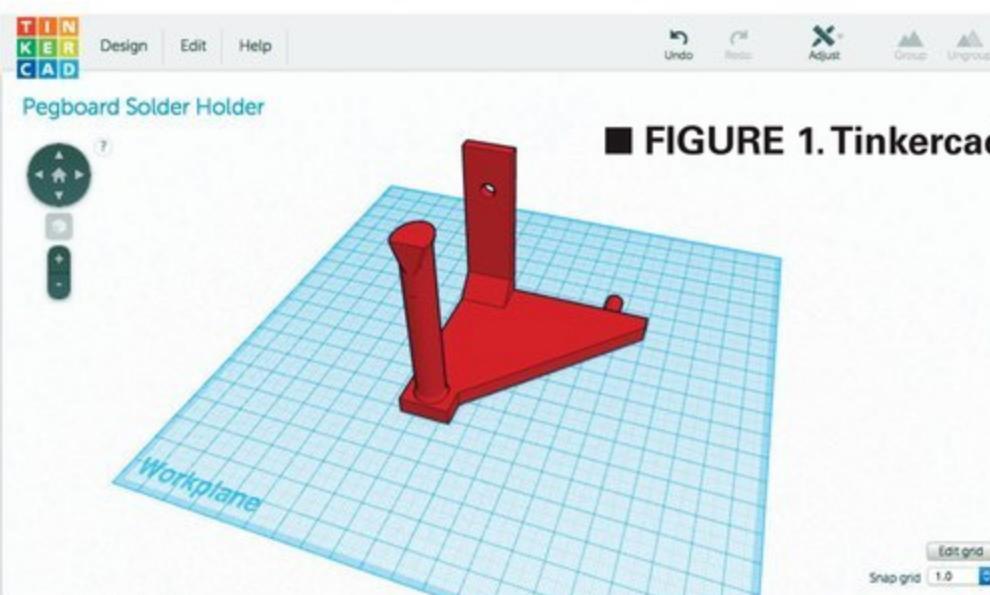
**Figure 2** shows the blocks that create the final design. The light gray blocks are the holes where material is removed. I squared off the edges of two parts because I

thought it looked better.

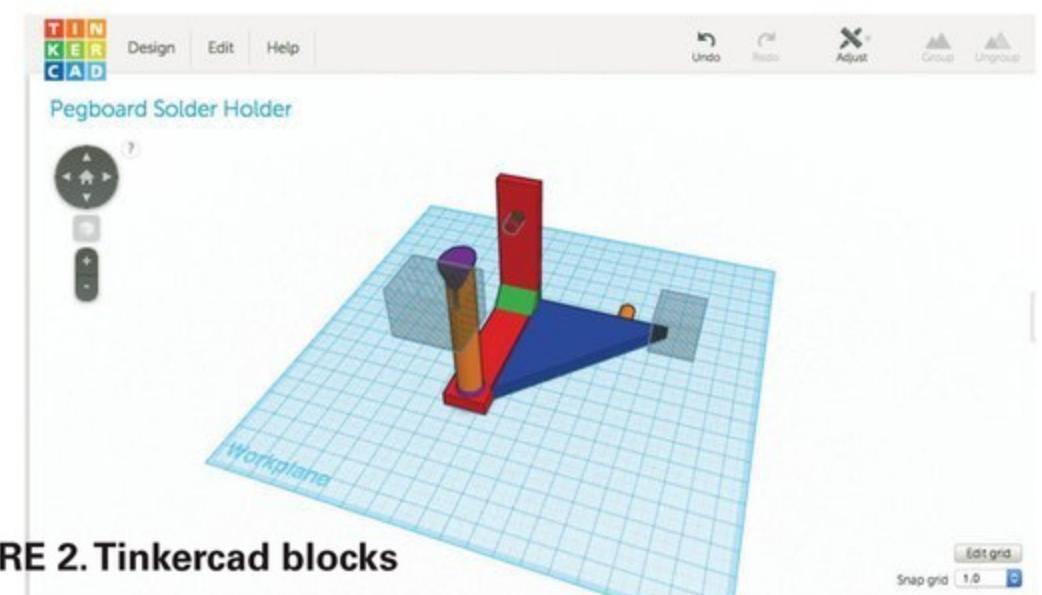
In Tinkercad, I just select all the objects and then group them together to make the final piece. When the design is complete, it can be exported as an .STL format file so it can be imported into the XYZware software I use for slicing the file and sending it to my da Vinci 1.0 printer 3D printer.

I made the design public, so anybody can copy it and modify the source file in Tinkercad to fit their requirements. I also uploaded the .STL file to my [Thingiverse.com](http://Thingiverse.com) account, so anyone can print the same design I created.

I printed the holder with the post sticking straight up. This eliminated the need for support material. This is not the best way to print it for strength, however, as the layers can potentially sag if the solder roll is too heavy. Printing it length-wise would be stronger but some support would be required, and that means extra plastic to use and extra work to remove it. I also thought at some point I could redo the design with a hollow shaft and then insert a metal rod inside for strength. That is actually a popular 3D print technique: Pause the print near the top of the post; insert

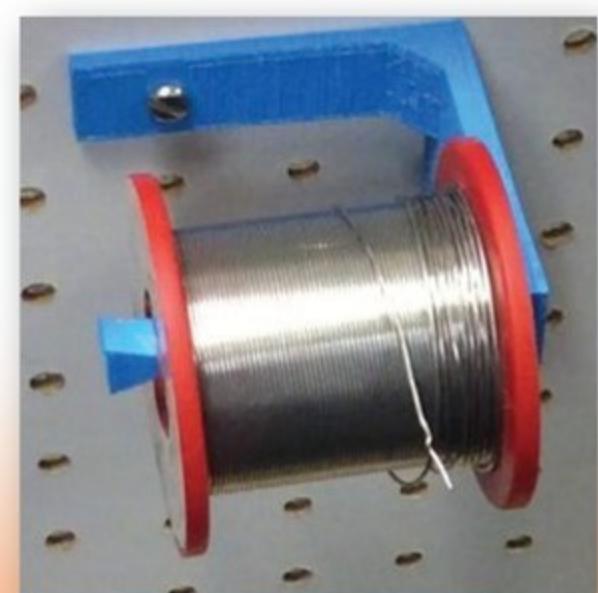


■ FIGURE 1. Tinkercad design



■ FIGURE 2. Tinkercad blocks

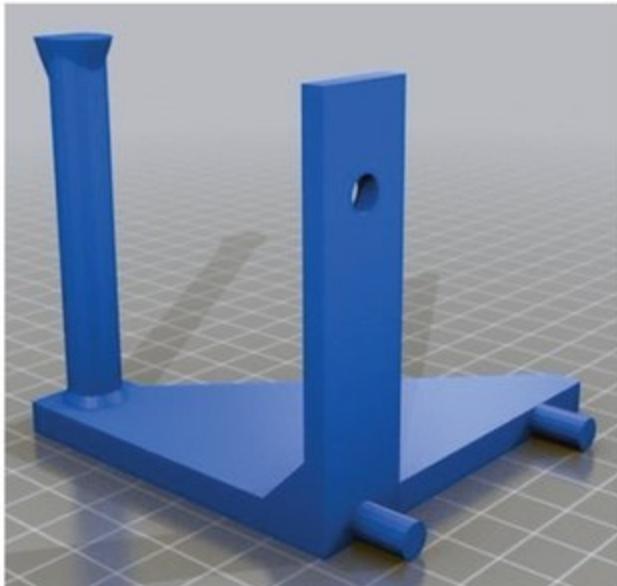
Using 3D printers for practical projects on your workbench.



■ FIGURE 6. Final design mounted to my bench.

## REAL WORLD USES FOR THE ELECTRONICS EXPERIMENTER

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■ FIGURE 3. Print Position

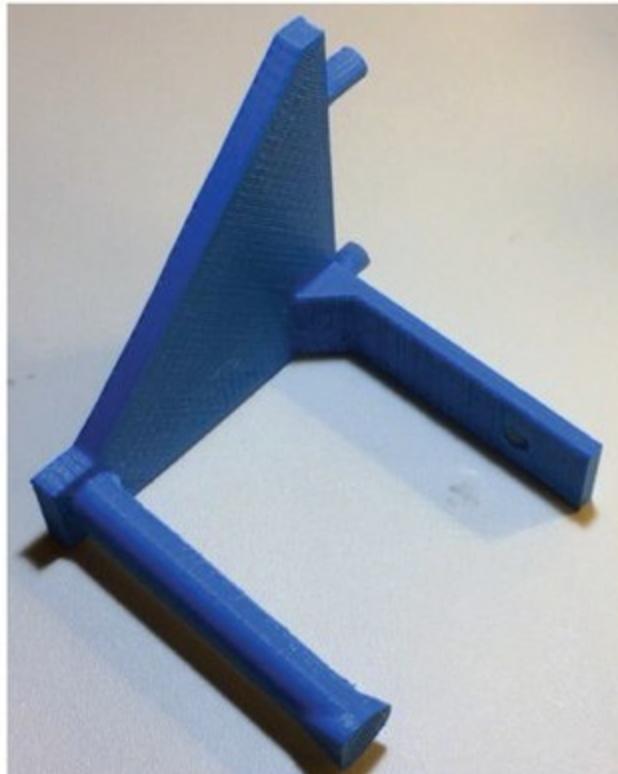
the metal rod; and then let the print finish – that covers up and traps the metal rod inside. I found I didn't need this though, as it was strong enough for me.

The final design in **Figure 3** shows the Thingiverse 3D presentation of the object based on the file, and **Figures 4** and **5** show the finished print. You can see they look very similar. I used a 0.2 layer height and a 50% fill to give it strength. It took 3-1/2 hours to print and 8-1/2 meters of filament. At the current price of \$28 for a cartridge of XYZprinting filament, the bracket cost about \$1 in plastic.

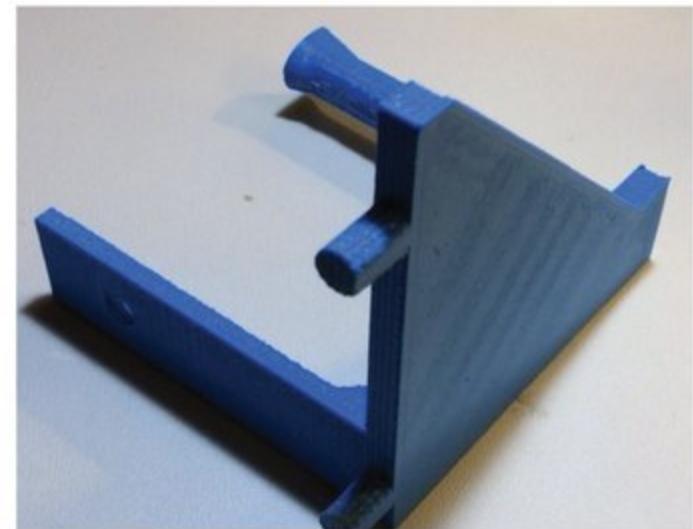
**Figure 6** shows the solder holder mounted to my bench. It works great! My son liked it so much he had me print several for his job where they build up electronic boards. He also used the same design to hold wire spools (**Figure 7**), then added a tube above the reel with a small slot so he could guide the wire and solder down to the user's hands. I probably could have 3D printed that guide tube as well, but sometimes just a standard off-the-shelf plastic tube will work fine.

They've been in use for many months now with very little issue. A new roll of solder will cause the bar to sag a little, but it springs back as the weight reduces.

The ideas for what else could be mounted to the pegboard with a custom bracket are endless. I've seen



■ FIGURE 4. Mounted Position



■ FIGURE 5. Back View

screwdriver racks, digital caliper mounts, jumper wire racks, and many more useful mounting ideas. The fact that you can customize it to fit your specific tool is

what makes 3D printing your own tool holders so great. You can create the design any way you want instead of trying to find something that might work.

You could just design something out of wood, but that requires you to make all the cuts, put it together, and then if you want another, repeat the whole process. The 3D printer does all the work once the design is set, and that is a total time saver. I set up many prints before I go to bed, so in the morning, the design is ready to use.

Making my lab more organized is always a challenge, as I tend to let stuff pile up on top of my bench. So, making a custom-mounting bracket like this is not only easy and cheap, but extremely useful.

There are many more 3D printed pegboard designs at **Thingiverse.com** that can be modified as necessary since you can import an .STL file into Tinkercad and then add or remove material to make it look how you want – even if you don't have the original design.

Let me know what you've printed or seen printed for an electronic hobbyist's workbench. Sharing ideas is what makes 3D printing so popular. **NV**



■ FIGURE 7. Wire and solder mounts.

## Resources

Check out my website and blog:

[www.elproducts.com](http://www.elproducts.com)

YouTube Channel:

[www.youtube.com/user/beginnerelectronics](http://www.youtube.com/user/beginnerelectronics)

My 3D designs:

[www.thingiverse.com/elproducts/designs](http://www.thingiverse.com/elproducts/designs)

Tinkercad:

[www.tinkercad.com](http://www.tinkercad.com)

Da Vinci 3D:

[us.xyzPrinting.com](http://us.xyzprinting.com)

SolderHolder Design:

<https://tinkercad.com/things/9WatYIIISTH>

## >>> QUESTIONS

### Headphone Hookup

My flat panel TV doesn't have a headphone jack. It has dual RCA jacks labeled "R/L line out" and a "TOSLINK" connector. What would be the simplest way to get my headphones hooked up to this TV?

#8151      **Chad Kessler**  
Marion, IN

### Dim Bulb

What's the difference circuit-wise between a "dimmable" and a "non-dimmable" 110V home LED light bulb?

#8152      **Jeremy Tores**  
Garden City, NY

### Servo Cycler

I would like to make a servo tester that would continuously run a servo from 0 to 180 degrees and back. I have found a number of 555 servo tester designs, but none that actually cycle the servo. Does anyone have a schematic for such a thing?

#8153      **Owen Corlis**  
Plymouth, MI

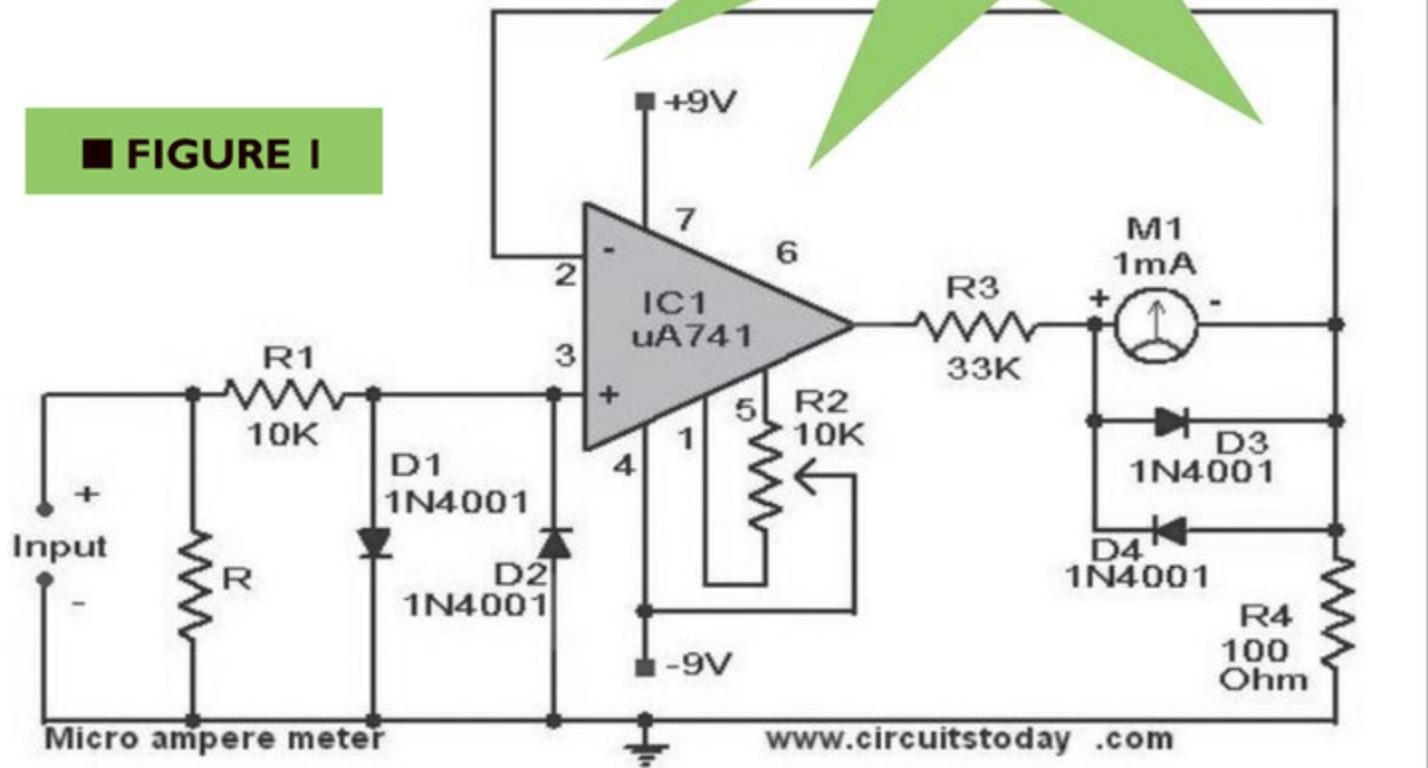
### Voltage Mod

I am trying to build a small micro ampere meter project I found on the Internet (**Figure 1**). The design calls for a +9V and -9V supply. Is it possible to modify this circuit to use a single 9V battery instead of two?

#8154      **Stephan Barth**  
Grand Bay, AL

All questions AND answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving technical problems. All submissions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted

■ FIGURE 1



[www.circuiststoday.com](http://www.circuiststoday.com)

## >>> ANSWERS

### [#6153 - June 2015]

#### Bipolar vs. MOSFET

I've read that bipolar transistors are current devices and MOSFET transistors – like old-fashioned vacuum tubes – are voltage-operated devices.

What does that mean from a practical perspective? For example, does this mean that bipolar are best for high power applications and MOSFETs are best for low voltage applications?

MOSFETs come in many flavors: there are N-type and P-type of course, but there is enhancement mode and depletion mode. Enhancement mode is off at zero gate voltage; you have to apply a positive gate voltage for N-type or a negative gate voltage for P-type to turn it on. N-type MOSFETs are available with

drain voltage ratings from 30V to 800V or more. Most MOSFETs are designed for switching; an 800V, 10 amp device would quickly burn up unless it could turn on and saturate even quicker.

MOSFETs are characterized by their saturation resistance which can be very low (like .01 ohms). Bipolar transistors on the other hand, are characterized by their saturation voltage which can't get as low power as MOSFETs. The threshold voltage (the point where the transistor just turns on) is not well controlled, so you can't really know what the drain current will be at a particular voltage. That makes it difficult to design a linear circuit. I avoid that problem by using bipolar transistors in linear circuits, or using pulse width modulation in a switching circuit which can be filtered to produce an analog signal.

Depletion mode MOSFETs are on at zero gate voltage and you have to apply a negative gate voltage to an N-type to turn it off. Junction FETs are also depletion mode devices and the zero gate voltage drain current is not well controlled, so they are usually binned and labeled so you have some idea of what you are designing with.

**Russell Kincaid**  
Milford, NH

by readers and **NO GUARANTEES**

**WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals.

*Always use common sense and good judgment!*

Send all questions and answers by email to [forum@nutsvolts.com](mailto:forum@nutsvolts.com)  
or via the online form at [www.nutsvolts.com/tech-forum](http://www.nutsvolts.com/tech-forum)

**[#7151 - July 2015]**

**PIR Hookup**

*My home alarm system has a motion sensor that has failed and the alarm company wants \$89 for a new one! I removed the bad one and it has screw terminals labeled:*

- \* GND
- \* 12V
- \* ALARM COM
- \* ALARM NC
- \* TAMP1
- \* TAMP2

*The simple PIRs I find for use with the Arduino are 5V and they don't have "tamp" pins. Can someone provide a schematic on how to hook up one of these low cost replacements?*

**#1** You only need to connect four wires for a burglar alarm motion detector to work properly. "GND" and "12V" are voltage for the motion detector – 12V is the positive, GND is the negative. "ALARM COM" and "ALARM NC" connect to the zone input on your burglar alarm panel. Typically, there is no need for polarity because this is a simple switch – with no motion in the area, the switch is closed; if motion is detected, the switch opens.

"TAMP1" and "TAMP2" are connected to a microswitch within the motion detector housing that activates your alarm if someone were to remove the cover – called a "tamper." If anything is connected to these terminals, you can simply twist the wires together, complete the circuit, and cap them off. It is not necessary to utilize the tamper feature and is often not recommended. But, I would avoid any type of "inexpensive" replacements for your alarm system motion detector. One of the major sources of false alarms in burglar alarm systems tends to be the motion detector. Installing a motion

detector not specifically designed for burglar alarm use may end up causing false alarms with your system and depending on your jurisdiction, fines from the local police department from the dispatching of those false alarms. Most burglar alarm motion detectors are designed to limit false triggers, so I would suggest going that route.

I did a quick search and could find a reliable motion detector listed for burglar alarm use for \$25. Easy enough to replace yourself; just make sure you seal up any penetrations in the housing where the wire and screws go through. Spiders love to make homes in these and that will also cause false alarms.

Alternately, \$89 may not be a bad price for your alarm company to replace the detector if that includes the labor. Nobody wants to work for free, after all! Plus, you can get them to quickly check your system to make sure it is communicating properly to your monitoring company and everything is working correctly.

**Eric D. Bailey  
Cecilton, MD**

**#2** There are several reasons an Arduino hobby type PIR is not a good substitute for a commercial PIR motion sensor.

**1)** You will need to step down the 12V to 5V with a voltage regulator. Coincidentally, page 78 of the July 2015 N&V Tech Forum has answers for a 5V regulator question.

**2)** You will need to add a 5V relay from the TTL output of your Arduino PIR so that you can provide floating form C (COM and NC) contacts for Alarm COM and ALARM NC. Normally, the ALARM contacts are closed unless an alarm condition is sensed. All sensors and switches in the ALARM loop are wired in series in a burglar alarm. Color code may vary, but in my experience a red and

a black wire were used. You should pay attention to the colors used in your system.

**3)** Unlike a commercial PIR, the Arduino PIR does not have an optical shield and/or shutters to adjust the beam width. As such, it will have a broader sensitivity and be susceptible to false alarms from moving persons or objects outside windows or pets inside. Additionally, it may be blinded from ambient light sources.

**4)** The terminals marked TAMP1 and TAMP2 are tamper switch connections. Normally, the tamper circuit is closed unless the sensor case is opened. In my experience, a white and green wire were used for tamper circuits. Yours may differ. If the tamper switch is opened in a commercial alarm system, a supervisory signal is sent to the alarm office and a technician is sent to inspect the system. This is to prevent a would-be burglar from opening the sensor and tampering with wires or placing tape over the PIR sensor. In a residential alarm system, a trouble light will appear locally at the control panel. With the above information, you can make the Arduino PIR function, however, the possibility for false alarms will be much greater unless you are willing to spend the time constructing a proper light shield.

The \$89 quoted by your alarm company sounds fair, and is an even better deal if they install it for that price. If you are under contract for alarm reporting to the central office, modification of the system may create problems with the agreement. You may be able to find an equivalent commercial sensor on e-Bay for a good price if you insist on replacing it. Personally, I would stick with a commercial PIR for this application.

**Joe Leikhim  
Oviedo, FL**

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- ✓ Low-cost GPS receiver timebase option!
- ✓ Programmable color LED tube mood lighting!
- ✓ The ultimate conversation piece!

This means they can be used in any country regardless of power frequency, with the included 12VDC regulated power supply. The clocks are also programmable for 12 or 24 hour mode, various AM/PM indications, programmable leading zero blanking, and include a programmable alarm with snooze.

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Display wise, the clocks feature a programmable night mode with dim or blank display, a programmable master blank tube saver, hard or soft fade digit change, and even have a built-in "Slot Machine" cathode poisoning prevention routine. Programming and setting the clock is a breeze with simple 2-button entries on the rear panel. The clocks are available in our signature hand rubbed Teak & Maple or futuristic clear acrylic bases.

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AC121 12VDC 1A Regulated Supply \$9.95

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The hit of the decade! Our patented receiver hears the entire aircraft band without any tuning! Passive design has no LO, therefore can be used on board aircraft! Perfect for airshows, hears the active traffic as it happens! Available kit or factory assembled.

ABM1 Passive Aircraft Receiver Kit \$89.95

#### Laser Trip Sensor Alarm

True laser protects over 500 yards! At last within the reach of the hobbyist, this neat kit uses a standard laser pointer (included) to provide both audible and visual alert of a broken path. 5A relay makes it simple to interface! Breakaway board to separate sections.

LTS1 Laser Trip Sensor Alarm Kit \$29.95

#### 12VDC Worldwide Supply

It gets even better than our AC121 to the left! Now, take the regulated Level-V green supply, bump the current up to 1.25A, and include multiple blades for global country compatibility! Dual ferrite cores!

PS29 12VDC 1.25A Global Supply \$19.95

#### Signal Magnet Antenna

The impossible AM radio antenna that pulls in the stations and removes the noise, interference, and static crashes from your radio! Also helps that pesky HD AM Radio stay locked! Also available factory assembled.

SM100 Signal Magnet Antenna Kit \$89.95

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For more than a decade we've been the leader in hobbyist FM radio transmitters. We told our engineers we wanted a new technology transmitter that would provide FM100 series quality without the advanced mixer features. They took it as a challenge and designed not one, but TWO transmitters!

For more than a decade we've been the leader in hobbyist FM radio transmitters. The FM30B is designed using through-hole technology and components and is available only as a do-it-yourself kit with a 25mW output very similar to our FM25 series. Then the engineers redesigned their brand-new design using surface mount technology (SMT) for a very special factory assembled and tested FM35BWT version with 1W output for our export only market! All settings can be changed without taking the cover off! Enter the setup mode from the front panel and step through the menu to make all of your adjustments. A two line LCD display shows you all the settings! In addition to the LCD display, a front panel LED indicates PLL lock so you know you are transmitting.

Besides frequency selection, front panel control and display gives you 256 steps of audio volume (left and right combined) as well as RF output power. A separate balance setting compensates for left/right differences in audio level. In addition to settings, the LCD display shows you "Quality of Signal" to help you set your levels for optimum sound quality. And of course, all settings are stored in non-volatile memory for future use! Both the FM30B and FM35BWT operate on 13.8 to 16VDC and include a 15VDC plug-in power supply. (*Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.*)

<b>FM30B</b>	Digital FM Stereo Transmitter Kit, 0-25mW, Black	\$199.95
<b>FM35BWT</b>	Digital FM Stereo Transmitter, Assembled, 0-1W, Black (Export ONLY)	\$299.95

## RF Preamplifier

The famous RF preamp that's been written up in the radio & electronics magazines! This super broadband preamp covers 100 KHz to 1000 MHz! Unconditionally stable gain is greater than 16dB while noise is less than 4dB! 50-75 ohm input. Runs on 12-15 VDC.

<b>SA7</b>	RF Preamp Kit	\$16.95
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## Mad Blaster Warble Alarm

If you need to simply get attention, the "Mad Blaster" is the answer, producing a LOUD ear shattering raucous racket! Super for car and home alarms as well. Drives any speaker. Runs on 9-12VDC.

<b>MB1</b>	Mad Blaster Warble Alarm Kit	\$9.95
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## Automatic VOX Voice Switch

This popular VOX switch provides a switched output when it "hears" sound! Use it to key a transmitter, turn on lights, or anything... all controlled by your voice! Runs on 6-12VDC.

<b>VS1</b>	Automatic VOX Switch Kit	\$9.95
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## Air Blasting Ion Generator

Generates negative ions along with a hefty blast of fresh air, all without any noise! The steady state DC voltage generates 7.5kV DC negative at 400uA, and that's LOTS of ions! Includes 7 wind tubes for max air! Runs on 12-15VDC.

<b>IG7</b>	Ion Generator Kit	\$64.95
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## Tri-Field Meter Kit

"See" electrical, magnetic, and RF fields as a graphical LED display on the front panel! Use it to detect these fields in your house, find RF sources, you name it. Featured on CBS's Ghost Whisperer to detect the presence of ghosts! Req's 4 AAA batteries.

<b>TFM3C</b>	Tri-Field Meter Kit	\$74.95
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## Code Practice Oscillator

A great starter kit for young and old! Learn kit building while building a great little CW practice oscillator to learn the code! Built-in key, built in speaker, and audio tone adjust! Runs on a 9V battery.

<b>CPO3</b>	Code Practice Oscillator Kit	\$17.95
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## Synthesized AM Transmitter Kit

The AM25 is not your ordinary hobbyist AM transmitter!

The AM broadcast band is quite alive and well, and is still considered the home of talk radio. For years the AM band has been a popular place for community broadcasts, in-home broadcasts, and other local information broadcasts. Now you can have a professional synthesized AM transmitter at the cost of a hobby unit!



The AM25 operates anywhere within the standard AM broadcast band, and is easily set to any clear channel in your area. The design is similar to that of a commercial radio transmitter, so while you build it you'll learn how the "big guys" operate. It is widely used by schools - standard output is 100mW with range up to 1/4 mile and is jumper settable for higher output where regulations allow.

There is no tuning or tweaking involved with the AM25. The PLL synthesized frequency is easily set with dip-switches and is rock solid without any drift, just like our FM25B. This is critical for any digital radio or tuner.

The transmitter accepts line level input from any audio source including CD players, MP3 players, computers, etc. Includes matching case & knob set and 110VAC power supply. Case measures 5" W x 1 1/2" H x 5 1/4" D.

(Note: The AM25B is a do-it-yourself learning kit that you assemble. Please remember that the end user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body in regards to the application and use of the AM25).

<b>AM25</b>	Synthesized AM Transmitter Kit	\$99.95
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## Electronic Siren

What an attention getter! Just hook up a speaker, battery and a switch. Close the switch for an upward wail and release it for the downward return. One of our most popular minikits! Runs on 9V battery.



<b>SM3</b>	Electronic Siren Kit	\$7.95
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## HV Plasma Generator

Generate 2" sparks to a handheld screwdriver! Light fluorescent tubes without wires! This plasma generator creates up to 25kV at 20kHz from a solid state circuit! Build plasma bulbs from regular bulbs and more! Runs on 16VAC or 5-24VDC.



<b>PG13</b>	HV Plasma Generator Kit	\$64.95
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## Speedy Speed Radar Gun

Our famous Speedy radar gun teaches you doppler effect the fun way! Digital readout displays in MPH, KPH, or FPS. You supply two coffee cans! Runs on 12VDC or our AC121 supply.



<b>SG7</b>	Speed Radar Gun Kit	\$74.95
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Need to "perk-up" your counter or other equipment to read weak signals? This preamp has low noise and yet provides 25dB gain from 1MHz to well over 1GHz. Output can reach 100mW! Runs on 12 volts AC or DC or the included 110VAC PS. Asmb.



<b>PR2</b>	Broadband RF Preamplifier	\$69.95
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## Active Receive Antenna

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<b>AA7C</b>	Active Receive Antenna Kit	\$59.95
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590 Fishers Station Drive  
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# WHAT'S HOT

## in Test & Measurement

### Oscilloscopes

#### Rigol



RIGOL's test & measurement instruments compete with industry leaders – but more affordably: Analog & Mixed-signal Scopes to 1GHz with AWG, Function/AWG from 20MHz-350MHz RF Signal Gens to 6GHz, Pwr Supplies, DMMs, & Spectrum

#### Owon



OWON's affordable, reliable, easy-to-use precision benchtop & handheld scopes are unbeatable in their price range. Battery powered and portable options for field use. Owon's Triple Output Power Supplies offer remote control & preset configurations.

#### Pico



PICO TECHNOLOGY - the world's best PC-based oscilloscopes & data acquisition equipment with the performance of good bench scopes; compact & lightweight - ideal for field work. Award-winning automotive scopes find engine & electric faults quickly.

### RF Test

#### Aim-TTI, Aaronia, Rigol



Affordable benchtop and handheld RF test tools measure free audio channels, find interference, emissions, noise, distortion, demodulate AM/FM signals, etc. Some include tracking generators to measure circuit frequency response automatically.

#### Telemakus

TELEMAKUS's - USB controlled, memory stick-sized RF devices build reconfigurable, complex, economical and portable RF test system with features of expensive benchtop systems. RMS detectors, Switches, Digital Attenuators, Vector Modulators & Synthesized Sources.



#### SWORD

SWORD Inc's custom, portable, quick-erect RF shielded enclosures provide superior RF shielding in fabric-based structures which attenuate RF signals from electronic equipment by up to 100dB, excellent for testing or eliminating electronic eavesdropping possibilities.



### Circuit/PCB Test

#### ABI Electronics



ABI ELECTRONICS - PCB test/repair: BoardMaster 8000: easy-use PCB test system; JTAGMaster: programs/tests via JTAG port; RevEng Schematic Learning System: generates schematics from PCBs; SENTRY: detects counterfeit components.

#### MQP



MQP ELECTRONICS – USB2.0 Analyzers /Gens, Protocol/Electrical Test equipment, offering unbeatable value/performance ratio and Vbus monitoring. GraphicUSB software offers full analysis of std USB2.0 protocol with Class Analysis options.

#### Cosview



COSVIEW - range of extremely affordable USB-connected inspection microscopes & stands, very useful for examining printed circuit boards and small integrated circuits for production faults or part number markings. Polarizing filter option which excludes surface glare is available.